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SUGGESTIONS REGARDING THE CLASSIFICATION OF THE IGNEOUS ROCKS

It may well be doubted if there is any science which presents greater difficulties to the teacher than that of systematic petrology—the classification of rocks. Even the name itself is seldom used, and appeals to the petrologist as almost a misnomer, because the science is so lacking in system, or, shall we say, overburdened by "systems." The German petrologists, under the leadership of Rosenbusch and Zirkel, and the French with Michel-Lévy at their head, are committed to the partial use of "systems" which are regarded as obsolete by their colleagues in other lands. The English and American schools of petrology have each their "systems" which differ from the German "systems" and more or less from each other. Yet as all are using essentially the same language of terms, the confusion which has arisen is so great that it is now necessary in employing a rock name to state at length what meaning the word is intended to convey.

Such a state of affairs is explainable on two grounds: first, the hesitancy felt in departing from the views held by the fathers of the science, and, second, the inherent difficulties which lie in the science itself, due to the complex nature of rocks.

The modern petrographical microscope, with its accessories, has introduced great refinement into the methods of study, so that descriptive petrology, or petrography, has become a very exact science. It is now possible to describe a rock in so many ways (in respect to so many of its attributes, such as mode of occurrence, texture, mineral composition, chemical composition, alterations, genesis, etc.,) that the difficulties in the way of bringing the results of the study into an orderly classification have been greatly increased. Nor is there reason to hope for any immediate remedy for this condition, since the largest and most representative body of petrologists ever assembled — the Seventh International Congress of Geologists, at St. Petersburg — was almost unanimous in the conviction that it would be useless to attempt to harmonize the nomenclature of the science by any early action of that body. The view was, however, expressed that something might be accomplished through the labors of a representative committee, which should, by frequent and careful deliberations, arrive at a tentative scheme for presentation to a future congress.

Undoubtedly the greatest obstacle in the way of reaching an understanding in the matter is that different values are assigned by different petrologists to the same attribute in rock classification. Some would lay greatest stress upon the mode of occurrence in the field; others would give the first place to mineral constitution, still others to texture, chemical composition, etc.

THE FIELD GEOLOGIST VS. THE PETROLOGIST

In deciding what shall be given first place as a basis in any system of rock classification, it should be realized, it seems to me, that the igneous rocks are not the sole property of the petrographer. The field geologist or the "naturalist," whatever be his special line of work, has need to make determination of igneous rocks, and he has a right to ask of the petrographer, who from his greater familiarity with rocks is charged with arranging them in an orderly system, such a classification that the geologist's determination in the field shall be *incomplete* rather

than *incorrect*. It should be made possible for the geologist to determine correctly at least the family to which a rock belongs, leaving to the petrographer the determination of rock species as well as the solution of the purely petrological problems.

To aid his eye the field geologist has only his pocket lens, and whatever rock species are fixed upon by petrologists they should be grouped into a comparatively small number of families, limited by simple and easily tested characteristics. In the case of the volcanic rocks it would be necessary to adopt terms broad enough to cover all rock types which it is found impossible to easily distinguish in the field. This reform would be made in the interest of the petrographer quite as much as of the geologist. If this be done the petrologist may multiply terms as he will to express any extension of his refined methods of study without in any way disturbing the composure or the effective work of the great body of field geologists.

BEARING OF RECENT PETROGRAPHICAL STUDIES ON ROCK CLASSIFICATION

From the point of view of the systematic petrologist the two most significant developments of petrology during the closing years of the nineteenth century have been, first, the numerous observations showing that the time honored families of igneous rocks, once supposed to be more or less sharply delimited, pass by insensible gradations into one another; and second, the return of chemical composition as a basis of rock classification to a position of prominence nearer to that which it formerly occupied.

The attention of petrologists was first drawn to the marked facial differentiation of a rock magma when the late Professor George H. Williams showed that rocks as diverse as quartz-mica-diorite and peridotite occur in the same stock near Peekskill, N. Y.[1] Since that time other investigators, but notably Iddings, Brögger, Ramsay, and Weed and Pirsson, have multiplied the

[1] G. H. Williams, The Gabbros and Diorites of the "Cortlandt Series," on the Hudson River near Peekskill, N. Y. Am. Jour. Sci. (3) XXXV, pp. 438–448, 1888.

observations of other but similar cases of magmatic differentiation. It is now the exception rather than the rule to discover an igneous rock mass of considerable dimensions in which some evidence of such gradations may not be observed.

The introduction of the petrographical microscope and its accessories, bringing as it did quick and delicate methods for determining the mineral constitution of a rock, naturally enough drew away the attention of petrographers from the slower and less brilliant methods of chemical analysis, which up to that time had been almost the only ones in use. Moreover most of the analyses of the period were, as we now know, inaccurate and failed to show the real chemical differences between individual rocks. The multiplication of the number of analyses and the improvements in the methods of rock analysis which have been made during the last decade, particularly by Hillebrand, have disclosed important differences among rocks formerly classed together, and thus necessitated a considerable elaboration of the systems of classification.

With this elaboration rock names have been introduced into the science with a rapidity which is little short of bewildering. The older petrological nomenclature was largely binomial or polynomial (*i. e.*, mica-syenite, quartz-mica-diorite) though the recent names seem planned for a monomial nomenclature (*i. e.*, ciminite). It is therefore not strange that misunderstanding has arisen in some quarters, where it is not realized that the new names proposed are for the most part specific and varietal in their nature and in no way to be correlated with the great family names such as granite or gabbro, and hence a protest has been made against what seems a needless overburdening of the science with names. Without entering upon this question here it may, I think, be stated with all assurance that some reforms are imperatively demanded before the worker will be fully equipped to discover the relationships among rocks because of the incubus of unclassified facts by which the science is now encumbered. Some of the particular reforms which to me seem desirable and practicable will be briefly described.

The definition of a rock as an object rather than as an integral part of the earth's crust.—The Wernerian conception of a rock as a geological unit or integral part of the earth's crust, still held by German petrologists, was adequate enough so long as rock masses were regarded as essentially homogeneous. With the discovery that such masses are usually quite heterogeneous and frequently represent not only several rock species but sometimes include almost the whole gamut of rock families, it became necessary to adopt some other definition. No other course seems open under these circumstances than to consider the individual rock specimen as the unit of classification and describe it primarily as an object, as is done with the units in the systems of other sciences.[1] If this is done it should be possible to *name* a rock from study of the specimen only though the *full description* would involve no less of field study than is undertaken when rocks are classified on the basis of their geological occurrence.

The importance of texture as a basis of classification.—All systems of classification of the igneous rocks emphasize more or less strongly rock texture as a basis of classification, for the reason that the texture is one of the properties of a rock most easily examined; and, further, because it is dependent so largely upon the peculiar conditions of rock consolidation or subsequent metamorphism. If rocks are described as objects this property of texture becomes inevitably of the very first importance.

The two main groups of the igneous rocks which are now generally recognized as distinguishable on the basis of texture are: first, those having a texture designated by Rosenbusch as *hypidiomorphic granular*, but which may in simpler language be referred to as *granitic*, the essential characteristic of which is that the mineral constituents by their manner of interlocking indicate for the rock in which they occur practically an uninterrupted period of crystallization; and, second, the *porphyritic*

[1] Cf. WHITMAN CROSS, The Geological *vs.* the Petrological Classification of Igneous Rocks. JOURN. GEOL. VI, p. 79, 1898. See also TEALL, British Petrography, p. 65.

texture in which the occurrence of two or more generations of the same constituent mineral indicates that the process of consolidation was not a continuous one but consisted of two or more stages.

The time honored but now obsolescent classification of igneous rocks on the basis of geological age has left us as a legacy a double nomenclature for the rocks of porphyritic texture, and this may be well illustrated by the terms "quartz porphyry" and "rhyolite" applied to rocks of porphyritic texture having a chemical composition similar to the granites. The former in its traditional, and also in its present German signification, refers to rocks of pre-Tertiary age, the latter to Tertiary or later rocks. The tendency of American petrographers seems to be to abandon entirely terms of the class of "quartz porphyry" and to extend the terms correlated with "rhyolite" to cover the rocks which were previously included in both groups. This tendency seems to me to be an unfortunate one since it results in classing together rocks which are essentially unlike. There may be no important difference between a particular "quartz porphyry" and a particular "rhyolite," but compare a drawer of hand specimens of the former with one of the latter and argument is unnecessary to show that as classes they are essentially different. The "quartz porphyries" are, as a class, devoid of vesicular and fluxion structures—they are in their mode of occurrence hypabyssal—and they more generally show the effects of devitrification, weathering, etc.

The "rhyolite" class of rocks may be conveniently distinguished from the "quartz porphyry" class by the possession of either vesicular or rhyolitic (fluxion) textures. Correspondence with some representative American petrographers has indicated to me that a restriction of the terms, rhyolite, trachyte, andesite, basalt, etc., to describe porphyritic types possessed of rhyolite or vesicular textures, would meet with considerable favor. Though of these terms rhyolite alone in its derivation calls attention to a fluxion texture, the others by their usage (trachytic structure, andesitic structure, etc.) have been given

the same significance. The terms, rhyolite-porphyry, trachyte-porphyry, andesite-porphyry, etc., by their substitution for the objectionable names, quartz-porphyry, quartzless porphyry, etc., would carry with them the idea of varietal rather than specific variation from the family type, and would, moreover, obviate the danger of their being interpreted in terms of the age classification.

Combination of chemical and mineralogical composition as a basis for rock classification.—Probably the majority of those petrologists who define rocks as objects would agree that chemical and mineralogical composition with texture should occupy the foremost places in rock classification.[1] It would probably be more satisfactory, were it practicable, to adopt chemical composition divorced from mineral composition as the primary basis in classification, but we are, per force, compelled to look first to the mineral composition, and work backward from this to the chemical composition—the chief factor in determining mineral composition. In the past the mineralogical examination of rocks has been largely qualitative, resulting, in some cases, in the classing together of rocks strikingly different as regards their ultimate chemical composition, but a stage has now been reached where such a method is no longer adequate. Pirsson has called attention to the necessity of paying greater regard to the relative quantities of the several essential constituents of a rock, thus making a rough estimation of its ultimate chemical composition.[2]

Specific, generic, and family rock names are applied to arbitrary rock types separated from one another by no sharp lines.—It follows, from the gradations generally observed to connect the families of the igneous rocks, that the names which we adopt to designate any individual rock, or class of rocks, is applied as a *type* name in the sense that it applies to a particular rock or collection of related

[1] Cf. TEALL: British Petrography, p. 69; WHITMAN CROSS: loc. cit., p. 80; J. P. IDDINGS: On Rock Classification, JOUR. GEOL., 1898, VI, p. 93; F. ZIRKEL: Lehrbuch der Petrographie, I, p. 829, 1893; W. C. BRÖGGER: Die Gesteine der Grorudit-Tinguait Serie, Christiania, 1894, p. 92.

[2] Igneous Rocks of Yogo Peak, Montana, Am. Jour Sci. (3) L, p. 478.

rocks, descriptions of which have been placed on record. The lines separating the several types are fixed arbitrarily, and would, in general, be located somewhat differently if undertaken at the outset by different individuals. For the types of larger order, these lines have been fixed by the traditional rock groups, and they are not likely to be much changed, but for the new and specific types they will be largely determined by the particular rock areas which are first examined.

A much more general use of intermediate family type names is inevitable, and terms like grano-diorite (or better, granito-diorite), trachy-andesite, etc., should be utilized.[1]

Rock relationships should be indicated by the combination of names into a binominal, or, if necessary, polynominal nomenclature.—The multiplication of specific terms, whose derivation has only a geographical signification (*e. g.*, Toscanite, Absarokite, Litchfieldite), furnishing not the slightest indication of the rock's relationships, is fast bringing petrologists to the condition of the Chinaman who is required to learn a unique syllable for every word in his language. Not possessing the admirable memory training of the Chinaman, the petrographer finds himself somewhat bewildered under the rain of new petrographical names which has characterized the closing years of the century. Many of these terms have been rendered necessary by the elaboration of the system of classification, due to the improved methods of chemical examination, and to the discovery of new petrographical provinces, and others are sure to be needed, but the enterprise in this branch of the science manifested in some quarters has sometimes provided us with two, or even three, names for the same specific rock type.

There can be no question that the nomenclature of petrography can be greatly simplified by a return to a binomial or polynomial nomenclature, which, fortunately, can be accomplished without much confusion, provided the old names of rock families be retained, together with compound names for the gradational types connecting them. An illustration may be

[1] Cf. BRÖGGER: op. cit., p. 93.

furnished by the interesting types, Toscanite, Vulsinite, and Ciminite, recently described by Washington.[1] They form together an intermediate family connecting the trachytes with the andesites, and called by Washington, trachy-dolerite, though it seems to me trachy-andesite is to be preferred. Trachy-dolerite-ciminite, or trachy-andesite-ciminite, is a term which tells at once that the rock to which it applies is a species of trachy-andesite which has been described from Monte Cimino. The term latite proposed by Ransome[2] for this group, while otherwise appropriate, fails to show the family relationships. Van Hise[3] has already suggested such a compounding of terms to express relationships. Certainly if the nomenclature of the science is to aid rather than to distract the worker some such reform from present conditions is demanded.

Graphical methods essential to a comprehensive study of rock analyses.—The necessity for studying the chemical composition in connection with the mineral composition of a rock requires that we examine in connection with one another the chemical analyses of all rocks having the same mineral constituents; or, better, those having the same constituents in the same relative quantities to a rough approximation. Such analyses show variations of one, two, or more per cent. in the quantities of some of the constituents for a single species or variety. But, on the other hand, differences of one or two per cent. in the amount of a constituent may be the cause of important differences in mineral composition or in other characteristics of the rock; hence it is important to know to that degree of precision the amount of each constituent which is present. For each analysis that would be remembered, it is necessary, then, to keep in the mind eight numbers of one or two figures each; and the student of petrology who would be familiar with the chemical nature of any

[1] H. S. WASHINGTON: Italian Petrological Sketches, No. 5, JOUR. GEOL., V, pp. 349–377, 1897.

[2] F. LESLIE RANSOME: Some Lava Flows of the Western Slope of the Sierra Nevada, Cal., Am. Jour. Sci. (4), V, p. 373, 1898.

[3] C. R. VAN HISE: The Naming of Rocks, JOUR. GEOL., VII, pp, 691–693, 1899.

given rock type must know the range in the percentages of the eight principal constituents. Moreover, he is not assisted in this by the knowledge that the upper and lower limits which he learns for a constituent of one species are at the same time, respectively, the lower and the upper limits for the same constituent in other allied species. A tax is thus imposed upon the memory far beyond what it may be reasonably expected to bear, and this tax is increased with the fixing of each new rock species.

The eye assists the mind not only to discover intricate relationships, but also to retain them, whenever the facts can be expressed by a definite form. This has been appreciated especially by the engineering profession, which has been accustomed, by the use of diagrams, to set forth in the most lucid manner facts which only the most laborious methods could otherwise bring out of the tables on which they are based. A curve contains the essence of pages of figures, and is readily carried in the mind owing to the large development of that faculty, which the Germans have so aptly termed *Vorschauungsgabe*. It is noteworthy that so little attempt has been made to apply graphic methods in petrology.

Recently, however, Iddings,[1] Becke,[2] Michel-Lévy[3] and Brögger[4] have each devised diagrams to illustrate rock analyses.

Of these the diagrams of Brögger seem to me the ones best adapted for general use because the simplest and the most characteristic. In the Brögger[5] diagram are set off on radius vectors the amounts of the eight principal chemical constituents reckoned

[1] J. P. IDDINGS: The Origin of the Igneous Rocks, Phil. Soc. of Washington. XII, pp. 89–214. Pl. II, 1892; Absarokite-shoshonite-banakite series. JOUR. GEOL., III, pp. 90–97, 1895; On Rock Classification, *ibid.*, VI, p. 92, 1898; Chemical and Mineralogical Relationships in Igneous Rocks, *ibid.*, p. 219.

[2] F. BECKE: Die Gesteine der Columbretes. TSCHERMAK'S min. u. petrog. Mittheil., VI, p. 315. 1897.

[3] M. MICHEL-LÉVY: Porphyr bleu de l'esterel, Bull. de la sèrvice de la carte géol. de la France. Tome IX, No. 57, 1897; Sur une nouveau mode de co-ordination des diagrammes representant les magmas des roches éruptifes. Bull. de la soc. géol. de la France. (3) XXVI, p. 311.

[4] W. C. BRÖGGER: Die Eruptivgesteine des Kristianiagebietes; Das Ganggefolge des Laurdalits. Kristiania, 1898, p. 255. Pl. I.

[5] Or LÉVY-BRÖGGER diagram.

in molecular ratios, ferrous and ferric iron being entered upon the same radius vector, and silica, because so much in excess of the others, being evenly divided between the two horizontal radius vectors. A broken line joining the intercepts on the eight radius vectors forms a polygon, which may be long and narrow, or short and thick, convex above or below, or reëntrant in any portion, left or right handed, etc., according to the chemical constitution of the rock.

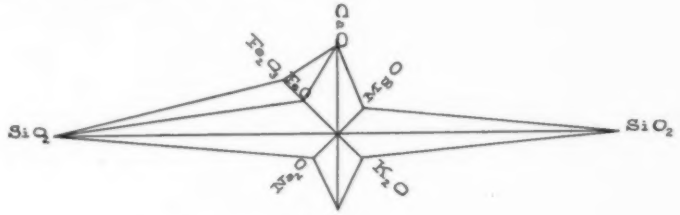


FIG. 1.

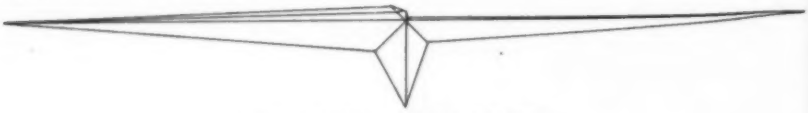
When viewed in this diagram, the rock comes to have a handwriting by which it may be instantly recognized. When drawn to scale, this diagram not only shows the chemical character of the rock but all the results of analysis may be quickly read from it numerically.[1] In it, as in all other successful diagrams the molecular ratio is substituted for the percentage of each constituent. Some authors now publish these ratios with every rock analysis. It is to be hoped that this will soon become a general custom.

THE COMPOSITE ROCK DIAGRAM

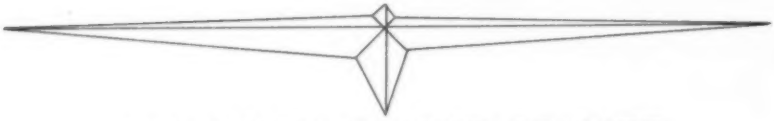
The principal objection to Brögger's diagram is that it represents not a rock species or a rock type but only an individual analysis, the rock type covering a considerable range of differing analyses. So far as I know, only isolated attempts have been made to average rock analyses to secure an adequate conception of the chemical constitution of the rock type, although the method of averaging results is so successfully used in other fields of science.

[1] On plates I, IV, V, and VI, .01 equals 1^{mm}.

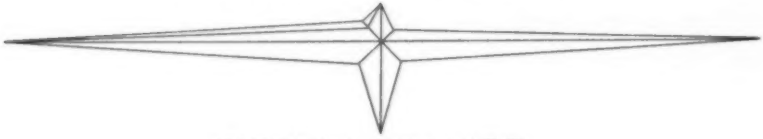
JOUR. GEOL., VOL. VIII, No. 1 Plate I



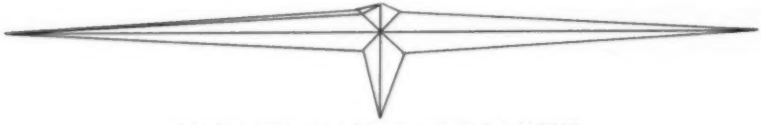
ALKALI GRANITE



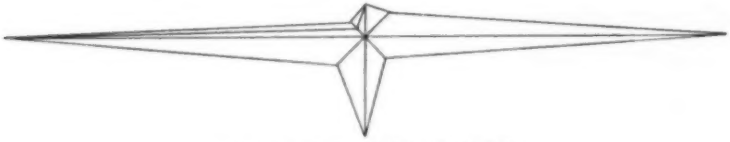
MUSCOVITE-BIOTITE GRANITE



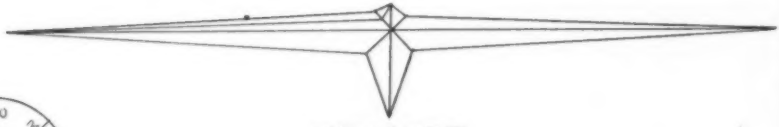
BIOTITE GRANITE



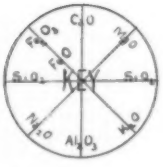
HORNBLENDE GRANITE



AUGITE GRANITE



GRANITE



COMPOSITES

In connection with his class in petrology, the writer has for some time made use of diagrams which set forth the average composition of rock types. There are two ways in which such diagrams may be constructed. On the one hand, the diagram may be prepared after the same manner as composite photographs. The Brögger diagrams of a considerable number of representative rocks faintly outlined are superimposed upon the same radius vectors, so as to indicate the range in ratios of each constituent and in the darkest part of the figure the characteristics of the type. A composite diagram, better adapted for general use, because so much less intricate and so much easier to prepare, is obtained by first averaging the molecular ratios of each constituent for the group of analyses, and using the results to prepare a single diagram, which then becomes the diagram of a type instead of that of an individual.

The writer has so far modified the Brögger diagram as to draw the radius vectors so as to make equal angles with one another. The closed polygon obtained by connecting the intercepts on the different radius vectors has a form which changes in a marked degree to correspond with the changes in the length of any radius vector. Since the soda, potash, and alumina are all measured below the horizontal, acid rocks show diagrams stretched out along the horizontal and developed also below the horizontal; while the protoxide bases being all entered above the horizontal basic rocks are short and "fat above." Soda-rich or potash-rich rocks give respectively left-handed and right-handed diagrams, etc. All these facts the eye soon accustoms itself to take in at a glance and subconsciously, as it does in the case of handwriting. It is hardly necessary for the eye to estimate the lengths of the intercepts (a feat it is but poorly qualified to accomplish) for the ratios of the quantities of the constituents to one another is shown by the *angles of slope* of the polygonal sides — something which the eyes easily measures. The larger the number of correct and properly selected analyses which are utilized in obtaining the "composite" of any type, the greater is its value.

JOUR. GEOL., VOL. VIII, No. 1 Plate II

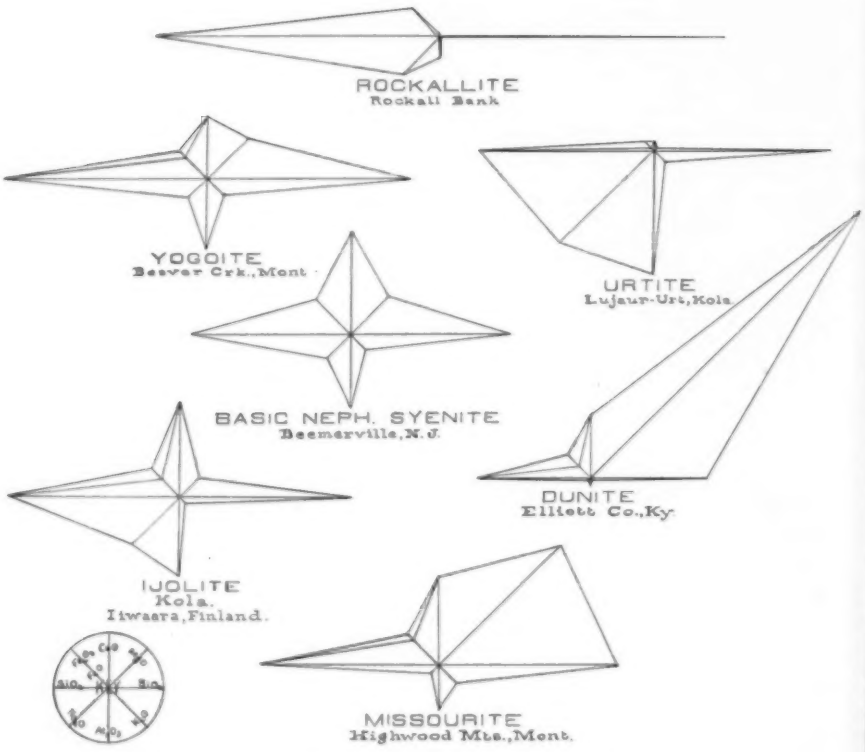
STUDY OF THE COMPOSITES OF THE PRINCIPAL FAMILY TYPES OF THE IGNEOUS ROCKS HAVING GRANITIC TEXTURE

The composite diagram may be made to represent either specific or family types according to the analyses which are combined to produce it. By combining separately analyses of the principal species of granite, viz., alkali-granite, muscovite-biotite-granite, biotite-granite, hornblende-granite, and augite-granite, we are prepared to draw the composite diagram of each and can then compare them with one another; or, if we choose, we may compose all to form a single composite, which then represents not a specific but a family type—granite. These granite composites may be studied in Plate I. The alkali-granite composite is composed from six analyses, the muscovite-biotite-granite from two, the biotite, hornblende, and augite-granites each from four, so that the family composite is made from the average of twenty analyses.

The composites of each of the families of the igneous rocks having granitic textures may be similarly prepared and studied in connection with one another. (See Plate II). The family types selected, viz., granite, syenite, alkali-syenite, nephelene-syenite, shonkinite, theralite, essexite, diorite, gabbro (including hypersthene-gabbro and norite), pyroxenite, and peridotite, when seen in their composites allow their peculiar characteristics to be read at a glance.

The granites are distinguished from all the other families by their excess of silica and, moreover, by the small quantities of the protoxide bases and moderate amounts of alumina and the alkalies. *The granites, alkali-syenites, and nephelene-syenites form a progressive series which is characterized by decreasing silica and rapidly increasing soda and alumina, and to a less degree by increasing potash and lime, so that the alkali and nephelene-syenite rocks become preëminently the alkali-alumina rocks.*

The shonkonites, theralites, and essexites form a second progressive series in which the silica and iron remain nearly constant but in which the potash, magnesia, and lime steadily decrease as the soda and alumina increase. The essexites are essentially alkali-diorites



SOME RARE ROCK TYPES
(GRANITIC TEXTURE)

distinguished from the diorites by a gain of alkalis, lime and iron, and a loss of silica.

The affinities of the syenites are seen to be entirely with the diorites and gabbros, with which they form a third progressive series which is continued imperfectly in the pyroxenites. In this series, characterized by generally decreasing silica and potash, the magnesia, lime, iron, and alumina increase, soda remaining practically constant throughout. The pyroxenites and peridotites, so poor in alkalis and alumina, show close affinity with each other and with the gabbros.

A few petrographical curiosities are represented in Plate III — rocks so exceptional in their occurrence as to be almost or quite unique. The first of these is Rockallite from Rockall Bank in the northeastern Atlantic,[1] a rock of granitic texture chemically closely related to the pantellerites of Fürstner (see Plate VII); Urtite is a nearly pure nephelene rock from the Kola peninsula[2] in arctic Russia which forms the limiting member of the nephelene-syenite family. Yogoite from Montana[3] is a "basic syenite." The "basic nephelene-syenite" from Beemerville, N. J.,[4] furnishes the most symmetrical of all the diagrams and gives indication of no near relationship to any other specific rock type though it is classed with the nephelene-syenites. The dunite from Elliott county, Kentucky[5] is so low in silica and so high in magnesia as to be very exceptional, though its diagram conforms to the general shape of the peridotite composite. Ijolite[6] and Missourite[7], the two recently

[1] JOHN W. JUDD: Notes on Rockall Island and Bank (Notice of Memoir) Geol. Mag., Dec., (4), VI, pp. 163–167, 1899.

[2] WILHELM RAMSAY: Urtit, ein basisches Endglied der Augitsyenit-Nephelinsyenit-Serie. Geol. Fören. Stockh. Förh., XVIII, pp. 459–468, 1896.

[3] WEED and PIRSSON: The Bearpaw Mountains of Montana, Am. Jour. Sci., (4), I, p. 357, 1896.

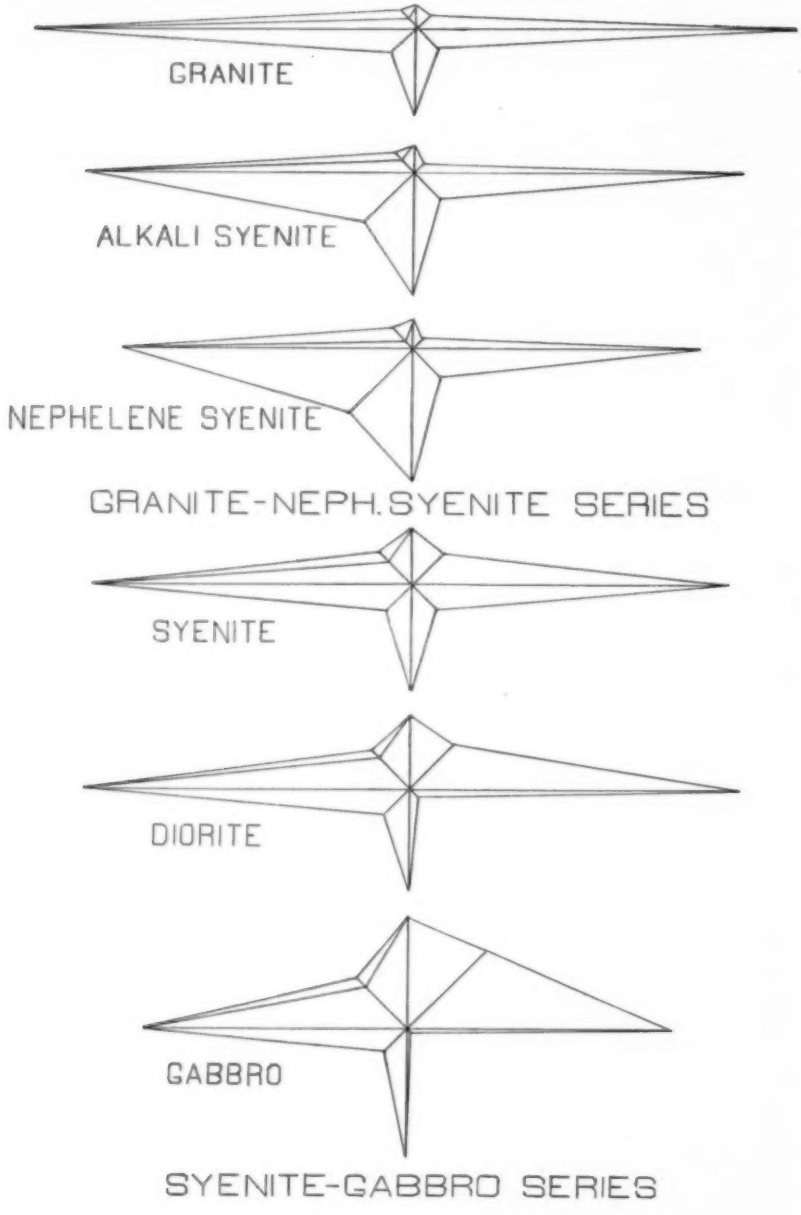
[4] J. F. KEMP: A basic Nephelene-syenite from Beemerville, N. J., N. Y. Acad. of Sci., XI, p. 68, 1892.

[5] J. S. DILLER: The Peridotite of Elliott County, Ky. Bull. No. 38, U. S. Geol. Survey, pp. 1–29, 1887.

[6] WILHELM RAMSAY: loc. cit.

[7] WEED and PIRSSON: Missourite, a New Leucite Rock from the Highwood Mountains of Montana. Am. Jour. of Sci., (4), II, pp. 315–325, 1896.

JOUR. GEOL., VOL. VIII, NO. 1. Plate IV



described types for which Rosenbusch has named a new family [1] are certainly remarkable types, but except for the quantities of silica, iron, and lime which they contain, they are as different from one another as two rock types can be imagined to be. Ijolite is rich in soda and alumina, Missourite poor; Ijolite is poor in potash and magnesia, Missourite rich to excess in both. Comparison of their diagrams with those represented in Plate II shows that they are the end members of the Shonkinite-Essexite series, Missourite fitting almost perfectly into the series, being only a trifle low in lime, and Ijolite failing to do so only being too high in lime and a bit too low in iron.

The igneous rocks of granitic texture when examined chemically fall, therefore, quite naturally into three progressive series, which have distinct and common characteristics.—These series may provisionally be designated by the limiting families of each, as the granite nephelene-syenite, missourite-ijolite, and syenite-gabbro series (Plate IV). The peridotites and pyroxenites do not fall perfectly into any of the three, but are yet closely allied to the syenite-gabbro series.

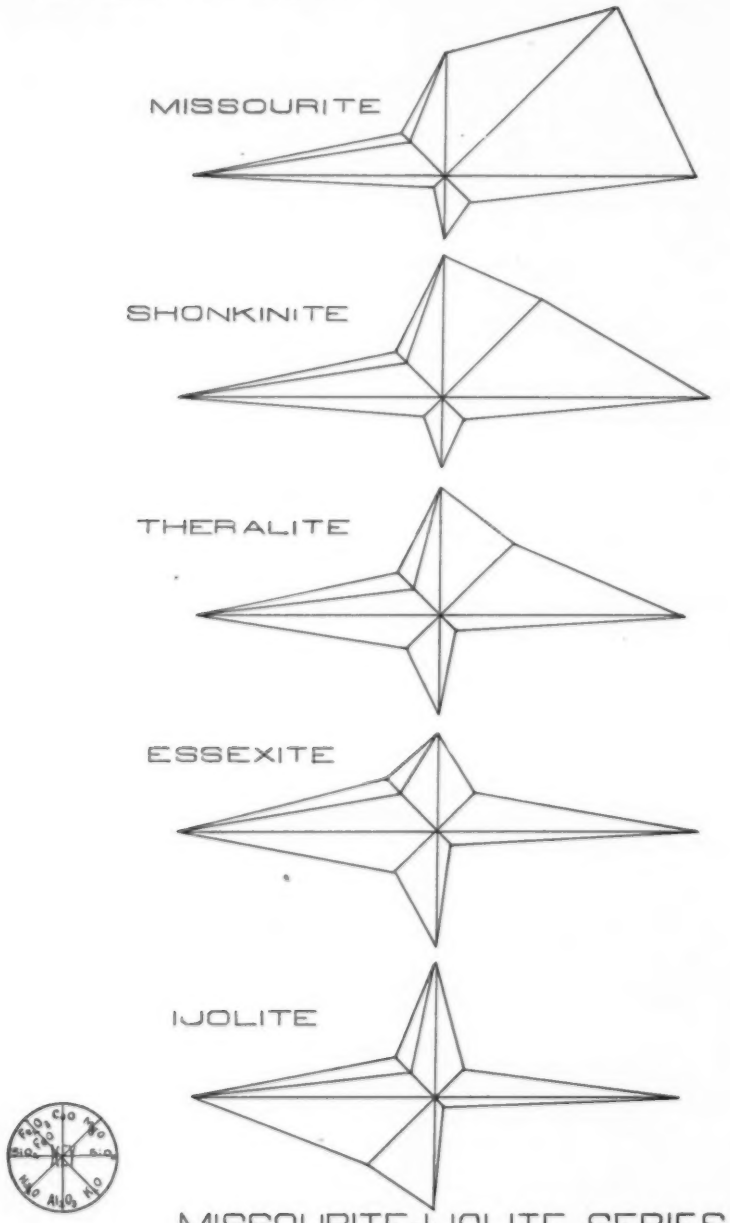
Granite-nephelene-syenite series	Missourite-ijolite series	Syenite-gabbro series
Granite family	Missourite family	Syenite family
Alkali-syenite "	Shonkinite "	Diorite "
Nephelene-syenite "	Theralite "	Gabbro "
	Essexite "	
	Ijolite "	Pyroxenite family
		Peridotite "

The composite diagrams of the granite-nephelene-syenite and syenite-gabbro series are shown in Plate IV, those of the Missourite-ijolite series in Plate V. The common characteristics of each of the series are well brought out by averaging the composites of the several members in each to form *series composites*, as has been done in Plate VI.

Composites of certain igneous rock types having rhyolitic texture.—No comprehensive attempt has yet been made to determine similar relationships among the rocks of rhyolitic texture, but composites of a considerable number of the specific rock types of

[1] ROSENBUSCH: Elemente der Gesteinslehre, p. 179.

JOUR. GEOL., VOL. VIII, NO. 1 Plate V



MISSOURITE-IJOLITE SERIES

acid and intermediate composition have been prepared. Plate VII displays together the composite diagrams of the specific types belonging to the families which Washington[1] has designated as the trachyte, trachy-andesite, trachy-dolerite, and andesite series.

The rhyolite diagram is a composite of nine analyses of rhyolites from Hungary, Ponza, the Auvergne, Nevada, and Colorado. The soda-rhyolite composite is compounded from six analyses, mainly of Wisconsin rocks soon to be described by C. K. Leith and the writer. The four pantellerites which furnish the pantellerite diagram are from the island of Pantelleria. The trachytes, six in number, are those of the Auvergne, Ischia, the Eifel, the Bohemian Mittelgebirge, and Monte Amiata; and the two domites were from the Auvergne. The vulcanite diagram is not a composite but an individual rock diagram made from the type analysis from Vulcano. The six dacite analyses composed were of rocks from Columbia, Guatemala, Lassen's Peak, Cal., and McClellan Peak, Nev., while the seven andesite analyses used in preparing the andesite composite were of mica- and hornblende-andesites from the Eureka district, Nev.; Custer county, Col.; Cartagena, Spain; the Siebengebirge on the Rhine; Panama; and Columbia. The Toscanite, Vulsinite, and Ciminite analyses are the Italian ones given by Washington,[2] and were respectively ten, ten, and eleven in number. The Banakites, Shoshonites, and Absarokites represented in the analyses are those described by Iddings[3] from the Yellowstone National Park and numbered four, five, and five respectively.

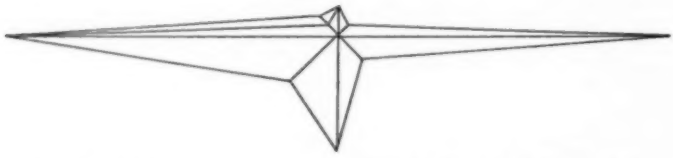
These *specific* composites are much less interesting as indicating relationships than the composites of a higher order would be, but they are here introduced to show that the composite diagram is capable of bringing out the chemical characteristics of rocks which differ only slightly from one another, as well as the characteristics of different families.

[1] H. S. WASHINGTON: Italian Petrological Sketches, V. JOUR. GEOL., V, p. 366. 1897.

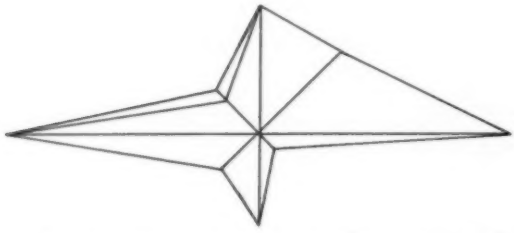
[2] H. S. WASHINGTON: loc. cit.

[3] J. P. IDDINGS: Absarokite-Shoshonite-Banakite series, JOUR. GEOL., III, pp. 935–959, 1895.

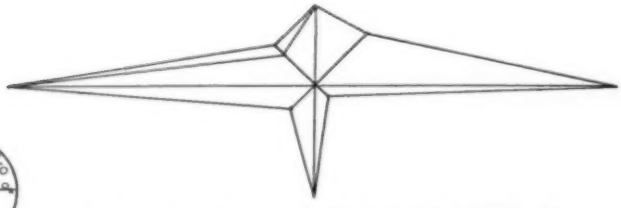
JOUR. GEOL., VOL. VIII, No. 1 Plate VI



GRANITE-NEPH. SYENITE SERIES



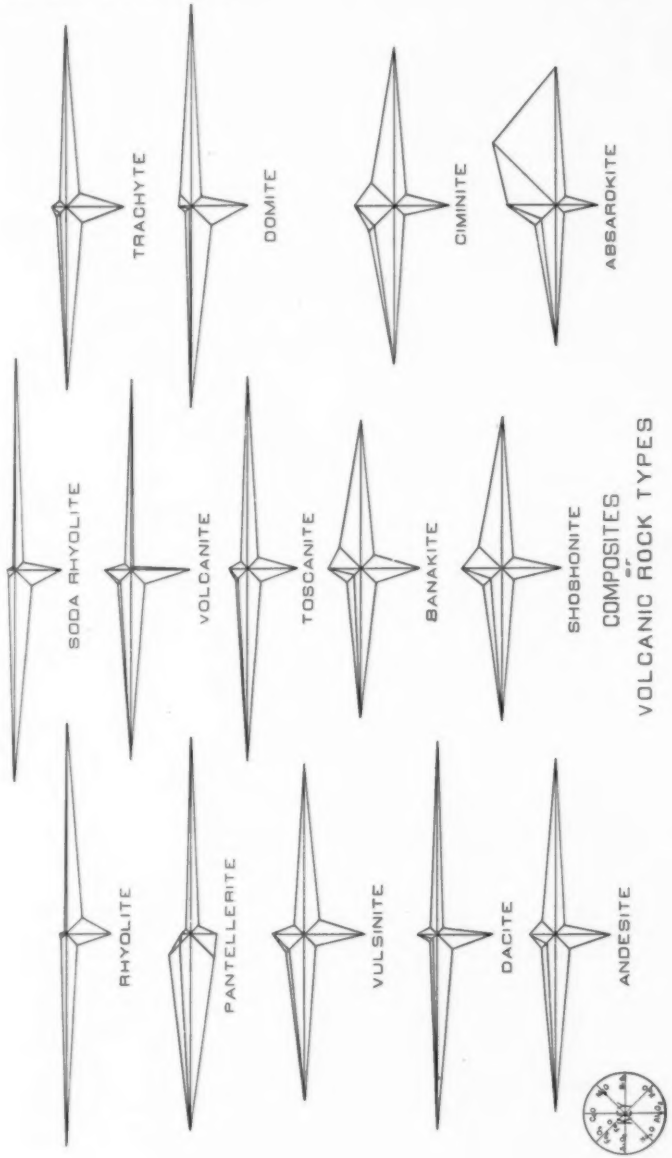
MISSOURITE-IJOLITE SERIES



SYENITE-GABBRO SERIES

SERIES COMPOSITES

JOUR. GEOL., VOL. VIII, NO. 1 Plate VII



In conclusion, I would suggest to all persons publishing analyses of rocks the advisability of printing beneath the figures showing the percentage, composition, the corresponding molecular ratios, and further, that the arrangement of oxides in the analysis be for the sake of uniformity that which has been consistently followed by Rosenbusch, Washington, and some others, and which is here used in the composite tables showing the averaging of analyses for the composite diagrams. The principal deviation from this order which I have observed is an inversion of the order of magnesia and lime or of soda and potash, which can hardly be regarded as essential. If these suggestions be followed, the work of those who examine rock analyses will be materially lightened and the liability to error in transcribing will be lessened.

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ROCKS WHOSE ANALYSES HAVE BEEN COMBINED TO PRODUCE THE COMPOSITES OF THE GRANITIC-TEXTURED IGNEOUS ROCKS

The greater number of the analyses of these rocks are to be found either in the tables of Rosenbusch's *Elemente der Gesteinslehre*, published in 1898 (abbreviation R), or in Clarke and Hillebrand's *Analyses of Rocks and Analytical Methods*,[1] published in 1897 (abbreviation C and H).

GRANITE[2]

1. Alkali-granite, Drammen, Norway.
2. Alkali-granite, Sandsvar, "
3. Alkali-granite, Pelvoux, Dauphinée, France.
4. Alkali-granite, Hardwick quarry, Quincy, Mass., Am. Jour. Sci. (4), 6, p. 181.
5. Alkali-granite, Montello, Wis., Hobbs and Leith. To be described in a forthcoming bulletin of the Geol. and Nat. Hist. Survey of Wisconsin.
6. Alkali-granite, Waushara Co., Wis., Bull. No. 3, Wis. Geol. and Nat. History Survey, 1898, p. 2.
7. Muscovite-biotite granite, Hautzenberg, Bayerischer Wald, Germany.
8. Muscovite-biotite granite, Katzenfels, Graslitz, Erzgebirge, Bohemia.

[1] Bull. 148, U. S. Geol. Surv.

[2] All the granite analyses with the exception of certain of the alkali granites are selected from Rosenbusch's list, on page 78 of the work cited.

9. Biotite-granite, Bobritzsch, Freiberg, Saxony.
10. Biotite-granite, Barr, Alsace.
11. Biotite-granite, Durbach, Black Forest, Baden.
12. Biotite-granite, Melibocus, Odenwald, Hesse.
13. Hornblende-granite, Mariposa Co., Nevada.
14. Hornblende-granite, Pré de Fauchon, Vosges.
15. Hornblende-granite, Syene, Egypt.
16. Hornblende-granite, ("Rapakiwi granite"), Finland.
17. Augite-granite, Laveline, Vogesen.
18. Augite-granite, Oberbruch, Dollerenthal, Alsace.
19. Augite-granite, Kekequabic Lake, Minn.
20. Augite-granite, Birkrem, Ekersund, Norway.

ALKALI-SYENITE

1. Nordmarkite, Tonsenaas, near Christiania, Norway. R. p. 112.
2. Pulaskite, Fourche Mt., Arkansas. *Ibid.*
3. Umptekite, Umpjaur, Kola Peninsula, Russia. *Ibid.*
4. Laurvikite, Laurvik, Norway. *Ibid.*
5. Sodalite-Syenite, Square Butte, Mont. *Ibid.*

NEPHELENE-SYENITE

1. Nephelene-Syenite, Salem Neck, Mass. Jour. Geol. **8**, p. 803.
2. Nephelene-Syenite, Great Haste Island, Mass. *Ibid.*
3. Litchfieldite, Litchfield, Maine. C. & H., p. 65.
4. Nephelene-Syenite, Red Hill, N. H. C. & H., p. 67.
5. Nephelene-Syenite, Fourche Mt., Arkansas. Igneous Rocks of Ark., p. 88.
6. Lujaurite, Umptek, Kola Peninsula, Russia. R. p. 126.
7. Nephelene-Syenite, Beemerville, N. J. C. & H., p. 80.
8. Basic Nephelene Syenite, Beemerville, N. J. N. Y. Acad. Sci. **11**, p. 68.
9. Nephelene-Syenite, Saõ Paolo, Brazil. R. 126.
10. Laurdalite, Lunde, Norway. Zeitsch. f. Kryst. **16**, p. 33.
11. Sodalite-Syenite, Kangersluarsuk, Greenland. R. p. 126.
12. Urtite, Lujaur Urt, Kola Peninsula, Russia. *Ibid.*
13. Leucite-Syenite, Magnet Cove, Ark. *Ibid.*
14. Borolanite, Lake Borolan, Scotland. *Ibid.*

MISSOURITE-IJOLITE SERIES

Missourite

1. Missourite, Shonkin Creek, Highwood Mts., Mont. C. & H. 154.

Shonkinite

1. Shonkinite, Beaver Creek, Bearpaw Mts., Mont. C. & H. p. 149.
2. Shonkinite, Yogo Peak, Little Belt Mts., Mont. *Ibid.*

3. Shonkinite, Square Butte, Highwood Mts., Mont. R. p. 176.
4. Shonkinite, Monzoni, Tyrol. Zeitsch. d. d. geol. Gesell. **24**, p. 201.
5. Nephelene-Pyroxene-Malignite, Poobah Lake, Canada. R. p. 176.

Theralite

1. Theralite, Gordon's Butte, Crazy Mts., Mont. R. p. 176.
2. Theralite, Martinsdale, Crazy Mts., Mont. *Ibid.*
3. Theralite, Umptek, Kola Peninsula, Russia. *Ibid.*

Essexite

1. Essexite, Salem Neck, Mass., Jour. Geol., **7**, p. 57.
2. Essexite, Salem Neck, Mass. R. p. 172.
3. Essexite, Isla de Cabo Fria, Rio de Janeiro, Brazil. *Ibid.*
4. Essexite, Mt. Fairview, Custer Co., Colo. *Ibid.*
5. Essexite, Rongstock, Bohemia. *Ibid.*

Ijolite

1. Ijolite, Iiwaara, Finland. R. 180.
2. Ijolite, Kaljokthal, Umptek, Kola Peninsula, Russia. *Ibid.*

SYENITE-GABBRO SERIES

Syenite

1. Mica-Syenite Frohnau, Black Forest, Baden. R. p. 106.
2. Mica-Hornblende Syenite, Silver Cliff, Colo. C. & H., p. 169.
3. Hornblende-Syenite, Plauenscher Grund, Saxony. R. p. 106.
4. Hornblende-Syenite, Biella, Piedmont. *Ibid.*
5. Monzonite, Monzoni, Tyrol. R. p. 109.
6. Monzonite, Yogo Peak, Mont. C. & H. p. 147.
7. Yogoite, Beaver Creek, Bearpaw Mts., Mont. C. & H. p. 156.
8. Akerite, Thingshoug, Norway. R. p. 111.

Diorite

1. Tonalite, Adamello, Tyrol. R. p. 140.
2. Banatite, Dognacska, Ranat, Austro-Hungary. *Ibid.*
3. Grano-diorite, near Bangor, Butte Co., Cal. C. & H. p. 204.
4. Diorite, Elk Mts., Colo., C. & H. p. 177.
5. Diorite, Electric Peak, Yellowstone National Park. C. & H. p. 117.
6. Amphibole-Diorite, Electric Peak, Yellowstone National Park C. & H. p. 118.
7. Augite-Diorite, Electric Peak, Yellowstone National Park. C. & H. p. 117.
8. Augite-Diorite, Peach's Neck, Mass. Jour. Geol. **7**, p. 60.
9. Diorite, Schwarzenberg, Vogesen. R. p. 140.

Gabbro

1. Anorthosite, Nain, Labrador. Zeitsch. d. d. geol. Gesell. 1884.
2. Orthoclose-Gabbro, Duluth, Minn. Neues Jahrb. f. Min. 1876, p. 117.
3. Gabbro, Northwestern Minn. C. & H. p. 112.
4. Garnetiferous Gabbro, Granite Falls, Minn. C. & H. p. 113.
5. Gabbro, Nahant, Mass. Jour. Geol. 7, p. 63.
6. Hypersthene-Gabbro, Baltimore, Md. Bull. U. S. Geol. Survey, No. 28, p. 39.
7. Norite, Montrose Point, Hudson River, N. Y. Am. Jour. Sci. (3) 22, p. 104.
8. Norite, Ivrea, Piedmont. R. p. 151.
9. Forellenstein, Neurode, Silesia. *Ibid.*
10. Forellenstein, Coverack, Cornwall. *Ibid.*

ULTRA-BASIC ROCKS

Pyroxenite

1. Websterite, Webster, N. C. C. & H. p. 92.
2. Bronzite-Diallage Rock, Hebbville, Md. C. & H. p. 84.
3. Hornblende-Hypersthene Rock, Gallatin Co., Mont. C. & H. p. 140.
4. Websterite, Johnny Cake Road, Md. R. p. 165.

Peridotite

1. Mica-Peridotite, Crittenden Co., Ky. C. & H. p. 94.
2. Scyelite, Achavarasdale Moor, Caithness. Quart. Jour. Geol. Soc. 41, p. 402.
3. Wehrlite, Red Bluff, Gallatin Co., Mont. C. & H. p. 140.
4. Lherzolite, Johnny Cake Road, Baltimore Co., Md. R. 165.
5. Saxonite, Douglas Co., Oregon. C. & H. p. 231.
6. Cortlandtite (Schillerfels) Schriesheim, Odenwald, Hesse. R. p. 165.
7. Bronzite Diallage Peridotite, Howardville, Md. Bull. U. S. Geol. Survey, No. 28, p. 54.
8. Dunite, Dun Mts., New Zealand. R. p. 165.
9. Dunite, Elliott Co., Ky. C. & H. p. 93.

Rare Rock Types

1. Rockallite, Rockall Bank, Atlantic. Geol. Mag. (4) 6, p. 165. 1899.
2. Basic Nephelene-Syenite, Beemerville, N. J. Trans. N. Y. Acad. Sci. 11, p. 86.
3. Urtite, Lujaur Urt, Kola Peninsula, Russia. Geol. Fören, Förh, 18, p. 462. 1896.
4. Ijolite, Iiwaara, Finland, and Umptek, Kola Peninsula, Russia. *Ibid.* 13, p. 300. 1891.
5. Missourite, Highwood Mts., Mont. Am. Jour. Sci. (4) 2, p. 315. 1896.
6. Dunite, Elliott Co., Ky. Bull. 38 U. S. Geol. Survey, p. 24. 1887.

COMPOSITES OF IGNEOUS ROCK TYPES OF GRANITIC TEXTURE

	Species of granite					Families of granite-neph.-syenite series			
	Alkali granite (6)	Muscovite-biotite granite (2)	Biotite granite (4)	Hornblende granite (4)	Augite granite (4)	Granite (20)	Alkali syenite (5)	Nepheline-syenite (14)	Composite
SiO_2	74.07 1.226	70.49 1.165	69.43 1.149	69.32 1.147	66.08 1.094	69.88 1.157	60.62 1.004	53.47 .885	61.32 1.015
TiO_2	.....	.33	.44	.31	.17	.31	.35	.26	.31
Al_2O_3 ...	13.48 .131	13.77 .135	14.54 .142	13.37 .131	15.81 .155	14.19 .139	19.13 .187	20.87 .204	18.06 .176
Fe_2O_3 ...	1.86 .012	3.69 .024	1.55 .010	1.40 .009	2.12 .013	2.12 .013	2.57 .017	4.93 .031	3.21 .020
FeO	1.29 .018	.02 .000	2.23 .031	2.97 .041	1.30 .018	1.56 .022	2.09 .028	1.27 .018	1.64 .023
						3.68	4.66	6.20	
MnO.....	.....	.....	.12	.....	.....	.02	.10	.07	.06
MgO	.16 .004	.87 .020	.96 .024	1.55 .039	2.17 .050	1.14 .028	.74 .018	.85 .021	.91 .023
CaO.....	.76 .012	1.78 .032	2.94 .053	2.38 .043	2.61 .046	2.09 .037	2.38 .042	2.70 .048	2.39 .043
Na_2O....	4.24 .068	3.82 .062	3.47 .048	2.84 .040	4.36 .061	3.75 .060	6.45 .104	8.26 .133	6.15 .099
K_2O	4.35 .046	4.36 .046	3.91 .042	4.30 .046	4.30 .046	4.24 .045	5.19 .054	5.55 .059	4.99 .053
H_2O	.63	.35	.66	.95	.61	.64	.90	1.32	.95
Others...	.....	.18	.05	.50	.....	.15	.23	.32	.23
Total ..	100.04	99.66	100.30	99.89	99.53	100.09	100.75	99.87	100.22

COMPOSITES OF IGNEOUS ROCK TYPES OF GRANITIC TEXTURE (*Continued*)

	Families of missourite-ijolite series						Families of syenite-gabbro series			
	Missourite (1)	Shonkinite (5)	Theralite (3)	Essexite (5)	Ijolite (2)	Composite	Syenite (8)	Diorite (9)	Gabbro (10)	Composite
SiO_2	46.06 .762	48.80 .808	44.67 .740	47.91 .793	44.71 .740	46.43 .769	58.73 .972	60.23 .997	48.40 .801	55.79 .924
TiO_2....	.73	.59	1.00	1.35	1.41	1.02	.65	.58	.61	.58
Al_2O_3...	10.01 .098	11.13 .108	15.58 .151	17.82 .174	17.46 .170	14.40 .141	16.78 .164	16.14 .158	20.06 .196	17.66 .172
Fe_2O_3...	3.17 .019	3.68 .023	5.28 .033	5.38 .030	5.15 .032	4.53 .022	3.05 .019	2.69 .017	2.99 .019	2.91 .018
FeO.....	5.61 .078	5.48 .076	4.85 .067	5.68 .079	3.71 .052	5.07 .070	3.79 .052	4.51 .063	6.40 .089	4.90 .068
	8.78	9.16	10.13	11.06	8.86		6.84	7.20	9.39	
MnO	.....	.07	.11	.02	.20	.08	.14	.02	.04	.07
MgO	14.74 .364	8.41 .210	6.31 .158	3.26 .081	2.67 .060	7.08 .177	2.77 .069	3.62 .090	6.73 .168	4.37 .109
CaO.....	10.55 .189	12.07 .216	11.05 .197	8.29 .148	11.50 .205	10.69 .191	4.82 .086	6.21 .111	9.38 .168	6.80 .121
Na_2O....	1.31 .021	2.33 .038	5.03 .071	5.45 .088	8.73 .141	4.57 .074	3.29 .053	3.40 .055	2.83 .045	3.17 .051
K_2O	5.14 .053	4.54 .047	3.10 .033	2.81 .030	1.82 .019	3.48 .036	4.96 .053	1.74 .019	.88 .009	2.53 .026
H_2O....	1.44	1.31	2.36	1.14	.67	1.38	.96	.58	1.84	1.13
Others...	.81	1.80	.31	.86	.85	.93	.46	.22	.02	.23
Total..	99.57	100.09	99.66	99.97	98.88	99.66	100.40	99.94	100.18	100.14

ULTRA-BASIC COMPOSITES

	Pyroxenite (4)	Peridotite (5)
SiO_2	52.58 .871	40.58 .672
TiO_2	.11	.77
Al_2O_3 ...	3.69 .036	3.64 .035
Fe_2O_3 ...	1.90 .012	5.89 .037
FeO	6.50 .090	5.88 .082
MnO.....	.11	.15
MgO	20.86 .521	30.00 .750
CaO	13.23 .236	5.60 .100
Na_2O....	.22 .003	.47 .007
K_2O	.10 .001	.55 .005
H_2O.....	.57	5.32
Others ...	.50	1.64
Total ..	100.37	100.49

RARE ROCK TYPES OF GRANITIC TEXTURE

	1 Rockallite	2 Basic nepheline-syenite	3 Urtite	4 Ijolite	5 Missourite	6 Dunite
SiO_2	73.60 1.218	41.37 .684	45.28 .749	44.71 .740	46.06 .762	29.81 .493
TiO_2	.....	.....	.....	1.41	.73	2.20
Al_2O_3 ...	4.70 .046	16.25 .159	27.37 .267	17.46 .170	10.01 .098	2.01 .019
Fe_2O_3 ...	13.10 .082	16.93 .106	3.53 .022	5.15 .032	3.17 .019	5.16 .032
FeO	.....	.....	.49 .007	3.71 .052	5.61 .078	4.35 .030
MnO	.93	.....	.19	.20	.....	.23
MgO	.11 .003	4.57 .113	.33 .009	2.67 .060	14.74 .364	32.41 .810
CaO	.37 .007	12.35 .221	1.22 .022	11.50 .205	10.55 .189	7.69 .137
Na_2O ...	6.96 .112	4.18 .067	17.29 .279	8.73 .141	1.31 .021	.11 .001
K_2O	.....	3.98 .042	3.51 .037	1.82 .019	5.14 .053	.20 .002
H_2O	.....	.45	.40	.67	1.44	8.92
Others ...	.06	.....	.....	.85	.81	7.77
Total ..	99.83	100.08	99.61	98.88	99.57	100.86

	Rhyolite (9)	Soda Rhyolite (6)	Pantellerite (4)	Trachyte (6)	Domite (2)	Volcanite (1)	Dacite (6)	Andesite (7)	Toscanite (10)	Vulsinite (10)	Ciminite [1] (11)	Banakite (4)	Shoshonite (5)	Absarokite (5)
SiO_2 ..	74.12	74.50	68.88	63.97	67.54	66.99	68.25	62.16	67.74	58.97	56.18	52.06	53.19	49.21
	1.227	1.233	1.140	1.069	1.118	1.109	1.129	1.029	1.121	.976	.930	.861	.886	.820
TiO_2 ..	.....	.....	.....	.36	.....	.....	.....	.23	.....	.....	.15	.76	.74	.92
Al_2O_3 .	13.21	13.67	8.01	17.62	16.96	17.56	16.35	16.45	14.77	17.84	16.24	17.66	17.81	12.52
	.129	.134	.078	.172	.166	.172	.160	.161	.144	.174	.159	.173	.174	.122
Fe_2O_3 .	1.14	1.22	6.72	2.01	2.97	1.41	1.78	3.27	.60	1.67	2.31	4.66	4.25	4.34
	.007	.008	.042	.012	.018	.008	.011	.020	.004	.010	.014	.029	.026	.027
FeO ..	.75	1.71	3.37	1.60	.37	3.39	1.19	2.71	3.15	4.67	6.17	2.20	3.07	4.15
	.001	.024	.047	.022	.005	.047	.016	.038	.044	.065	.086	.030	.043	.057
MnO ..	.....	.....	.....	.....	.13	.....	.01	.02	.....	.03	.23	.13	.11	.13
MgO ..	.15	.24	.62	.92	2.08	.93	1.21	2.20	1.06	1.67	3.95	3.33	3.64	10.36
	.004	.006	.015	.023	.051	.023	.030	.055	.024	.041	.098	.083	.091	.259
CaO ..	1.11	1.17	1.46	2.32	2.02	4.25	3.03	4.13	2.99	5.02	6.25	5.11	6.25	8.14
	.020	.021	.026	.041	.036	.076	.054	.074	.053	.090	.112	.091	.111	.140
Na_2O .	2.67	3.90	6.78	4.62	4.80	3 35	4.31	4.07	3.25	2.76	2.44	4.09	3.43	2.01
	.037	.048	.094	.064	.077	.054	.060	.056	.052	.045	.039	.057	.047	.028
K_2O ..	6.06	2.98	3.35	5.59	3.57	.34	2.48	3.45	4.16	5.86	4.44	5.03	3.88	3.74
	.063	.031	.035	.059	.038	.003	.026	.037	.044	.060	.047	.053	.041	.040
H_2O ..	.93	.39	.44	1.14	.39	1.53	1.09	1.15	1.92	1.34	1.59	3.74	2.73	3.96
Others.	.....	.....	.....	.03	.60	.....	.06	.15	.42	.24	.37	.84	.71	.71
Total	100.05	99.78	99.63	100.18	100.13	99.75	99.76	99.99	100.06	100.07	100.32	99.64	99.81	100.53

[1] The analyses on which this composite is based are too high in alumina and too low in magnesia. Cf. Washington, Am. Jour. Sci. (4) IX, p. 44, 1900.

DENTITION OF SOME DEVONIAN FISHES

During the last few years our knowledge of the multiplicity and relationships of the Middle and Upper Devonian fish-faunas in this country has been enlarged by the discovery of much new material. Exceptionally interesting finds have been made in the Marcellus, Hamilton, and Naples shales of New York, the Chemung-Catskill of Pennsylvania and its presumable equivalent in Johnson county, Iowa, in the Corniferous of Ohio, and in the Hamilton limestone of Wisconsin and adjoining states. From the last-named horizon notable collections have been brought together and rendered accessible for study by Messrs. E. E. Teller and C. E. Monroe and the late T. A. Greene of Milwaukee, and Professors Calvin and Udden of the Iowa State Geological Survey. These have been freely drawn upon in the preparation of the following notes.

GENUS *DINICHTHYS*, NEWBERRY

So intimately related are the two best-known Arthrodires, *Coccosteus* and *Dinichthys*, that the only crucial test of generic distinctness is afforded by the dentition. Likewise, for the discrimination of species, dental characters are all-important. Among the body-plates the chief distinctive characters are furnished by the dorso-median and clavicular.

1. *D. pustulosus* E. (Fig. 1). — Although remains of this Hamilton Dinichthyid are tolerably abundant, nothing was known of its dentition until recently, when one large premaxillary, nearly equaling that of *D. terrelli* in size, and two maxillary or shear-teeth were found by Mr. Teller in the hydraulic cement quarries of Milwaukee. Last fall a fragmentary mandible showing rudimentary denticles along the posterior slope of the cutting edge was obtained from the Hamilton of New Buffalo, Iowa, by Professor Udden, and still more recently Mr. Monroe

was fortunate enough to secure at the typical Milwaukee locality the specimen shown in Fig. 1.

The inner face of this specimen is attached to a block of limestone, a part of the anterior extremity is broken away, and a considerable portion of the posterior end is missing. The total length may be estimated at about 24^{cm}, the proportions being about the same as in *D. curtus*, and about three quarters the size of an adult individual of *D. intermedius*. The posterior

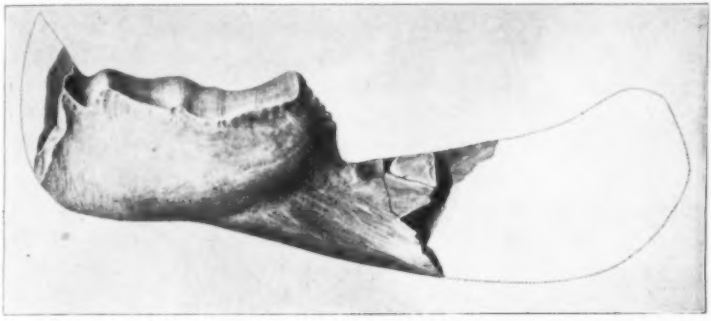

FIG. 1. *Dinichthys pustulosus* E. Hamilton; Milwaukee, Wisconsin. Left mandible. $\times \frac{2}{3}$.

end is more slender than in either of these species, and the cutting edge also differs in having no prominence back of the tooth-like beak. The cutting edge of *D. intermedius* has one such prominence, and that of *D. curtus* two. In *D. curtus* "the posterior end of the cutting edge is set with two or three unequal denticles in place of the series of even, lancet-like points in the same position on the mandible of *D. intermedius*."[1] But in the present form these denticles are reduced to mere swellings, of which five may be counted along the posterior slope of the cutting edge. Professor Udden's specimens, altho smaller, shows the bosses more prominently; they are, in fact, rudimentary denticles, and represent the initial stage of those structures which are such a conspicuous feature in *D. herzeri* of the Ohio Shale.

[1] NEWBERRY, J. S., Pal. Fishes N. A. (Mon. U. S. Geol. Surv., Vol. XVI, p. 156), 1889.

The cutting edge of the mandible is beveled to a sharp edge, and shows the usual indications of wear. It belonged to an average or slightly undersized individual, judging from the proportions of a dozen crania that have been found at Milwaukee. The largest of these, it should be noted, is only one fifth smaller than an averaged-sized head of *D. terrelli*. The premaxillaries and shear-teeth do not call for any special comment, except that the latter are without denticles on the posterior margin.

2. *D. halmodeus* (Clarke).—The presence in the type specimen of functional premaxillary teeth, and of a carinal process on the under side of the dorso-median, are sufficient reasons for transferring this species from *Coccosteus* to *Dinichthys*. The mandibles, which measure about 6.5^{cm} in length, have in place of a cutting edge a series of seven or more backwardly directed denticles. The anterior beak is missing in both mandibles, and the premaxillaries are also damaged. The latter are relatively very powerful, and provided with an elongated base for attachment to the visceral surface of the cranium. The plates designated as *x*, *mx*, *pmx*, and *pto*, in Dr. Clarke's diagram[1] are all parts of a single element, the suborbital. Examination shows that the cranial osteology and structure of the dorso-median are normal in every way.

3. *D. herzeri* Newb.—This species is commonly supposed to be limited to the Huron Shale, but it probably had a continuous range from base to summit of the Ohio Shale. Its occurrence in the Cleveland Shale may be strongly suspected, if indeed it is not proved by two specimens described by E. W. Claypole. The first is the fragmentary mandible known as *D. kepleri* Cl.,[2] and the second is the series of massive plates (plastron and clavicular) preserved in the Ohio State Museum, and figured in part in Vol. VII of the *Ohio Geological Survey Reports* (Pl. XXXVIII–XL). The clavicular and postero-ventro-median each have a length of about 50^{cm}, and the postero-ventro-laterals are over 76^{cm}

[1] Thirteenth Ann. Rep. State Geol. N. Y., Vol. I, 1893, p. 162.

[2] Amer. Geol., Vol. XIX, 1897, p. 322, Pl. XX.

long, indicating a creature about two fifths larger than the average of *D. terrelli*. Believing these proportions too large for any known species of *Dinichthys*, Claypole[1] referred the remains to *Titanichthys;* and later the name of *D. ingens* was suggested for them by Wright.[2] We propose to cancel both this title and that of *D. kepleri* in favor of the type species of *Dinichthys*. Other plates of huge size belonging in all probability to the same species are preserved in the museum of Kentucky State University at Lexington.

4. *D. clarki* (Claypole).—A large species of *Dinichthys* allied to the preceding, so far as may be judged from the dentition, was made the type of a new genus by Claypole,[3] and named by him *Gorgonichthys clarki*. No characters are shown, however, which warrant a separation of this form from *Dinichthys;* on the contrary, the mandible displays an interesting stage of modification between denticulated forms like *D. herzeri*, *D. halmodeus*, etc., on the one hand, and those with a sharp cutting edge like *D. terrelli* on the other.

The type of the so-called "*Gorgonichthys*" and the large premaxillary described by Claypole[4] as *Dinichthys clarki* have, of course, nothing in common. The relations of the latter are not accurately determinable. If excluded from *Dinichthys*, a new generic name will be required; if retained, a new specific name is necessary.

GENUS *CLADODUS*, AGASSIZ

This typically Carboniferous genus occurs sparingly in the Neodevonian, but no species have been reported from Mesodevonian horizons. That it was present, however, in both the Corniferous and Hamilton periods is proved by at least two specimens which have come under the writer's observation. One of these is a large tooth from the Corniferous limestone of Columbus, Ohio, now preserved in the American Museum of

[1] Rep. Ohio Geol. Survey, Vol. VII, 1893, p. 611.

[2] Bull. Mus. Comp. Zoöl., Vol. XXXI, 1897, p. 24.

[3] Amer. Geol., Vol. X, 1892, p. 1.

[4] *Ibid.*, Vol. XII, 1893, p. 278.

Natural History in New York (Cat. No. 4257). Although very similar to *C. striatus* Ag., it probably belongs to a distinct species.

C. monroei, sp. nov. (Fig. 3).—The type of this species is a small, imperfectly preserved tooth found by Mr. C. E. Monroe in the Hamilton of Milwaukee. The drawing reproduced herewith is made up from both halves of the counterpart containing the specimen. Traces of striae appear in places, but are nearly

FIG. 2. *Cladodus monroei* sp. nov. Hamilton limestone; Milwaukee, Wisconsin. × ⅞.

FIG. 3. Supposed cone-scale from Kinderhook fish-bed at Burlington, Iowa. × ⅞.

obliterated by decay of the enamel and dentine, and portions of the crown and base are broken away. The crown is robust, being very thick at the base, and the external denticles are proportionately stout. Three cusps of small size intervene on each side between the principal cone and external denticles. The total height may be estimated at about 1.3 cm, and the width of base at 2.5 cm.

Other Corniferous forms occurring in the same horizon at Milwaukee are teeth and plates of *Onychodus*, spines of *Machaeracanthus*, and Chimaeroid remains. *Macropetalichthys* and *Asterosteus*, however (which on account of their cranial osteology and lack of dentition we must now exclude from *Arthrodira* and place with the Ostracoderms as degenerate Elasmobranch offshoots), are conspicuously absent.

GENUS *DIPTERUS*, SEDGWICK AND MURCHISON

There are two distributional centers for this genus in America, between which there was apparently no communication. In the eastern province, which includes the Chemung-Catskill of New York and Pennsylvania, it is associated with forms common to the Upper Devonian of Canada and Europe. In the western province (Iowa and Illinois to Manitoba) it ranges from the base of the Hamilton to near the top of the Devonian and is accompanied by *Ptyctodus* and a number of Dipnoan forms peculiar to this region.[1] Here are found no traces of Crossopterygians or Ostracoderms; in fact the western Neodevonian fish-fuana is entirely distinct from the eastern, and represents a different migratory movement.

The Chemung proper contains but two well-recognized species of Dipterus, *D. flabelliformis* and *D. nelsoni*, the latter including Newberry's so-called *D. levis* (founded on worn specimens), and possibly *D. quadratus* and *D. minutus*. From the Catskill of Pennsylvania four species are known: *D. sherwoodi*, *D. fleischeri*, *D. angustus* and *D. contraversus* (= *D. radiatus* N.). Several of these species are founded on imperfect material, and the original descriptions require emendation. To this list may now be added four new species from the Middle and Upper Devonian of Iowa, the types of which are preserved in the Museum of Comparative Zoölogy at Cambridge, Massachusetts.

1. *D. uddeni*, sp. nov. (Fig. 5).—This species is established on a unique mandibular dental plate from the base of the Cedar Valley limestone (Middle Devonian) near New Buffalo, Iowa. It has a total length of 36^{mm}, is moderately convex, and remarkable for the paucity of its denticulated ridges. These are only four in number, and radiate in gently curved lines from the posterior angle, which is worn smooth by use. The anterior row of denticles and inner moiety of the remaining rows are also considerably worn; but in the outer moiety of these rows the denticles are acutely conical, of large size and well separated.

[1] Ann. Rep. Iowa Geol. Surv., Vol. VII (1896), Pl. IV; *ibid*, Vol. IX (1898), p. 302; Jour. Geol., Vol. VII (1899), p. 77.

There is a progressive diminution in size of all denticles proceeding posteriorly. The coronal surface is finely punctate.

This beautiful dental plate is the oldest of all *Dipterus* remains that have been found in this country. It was discovered by Professor J. A. Udden of Augustana College, Rock Island, in

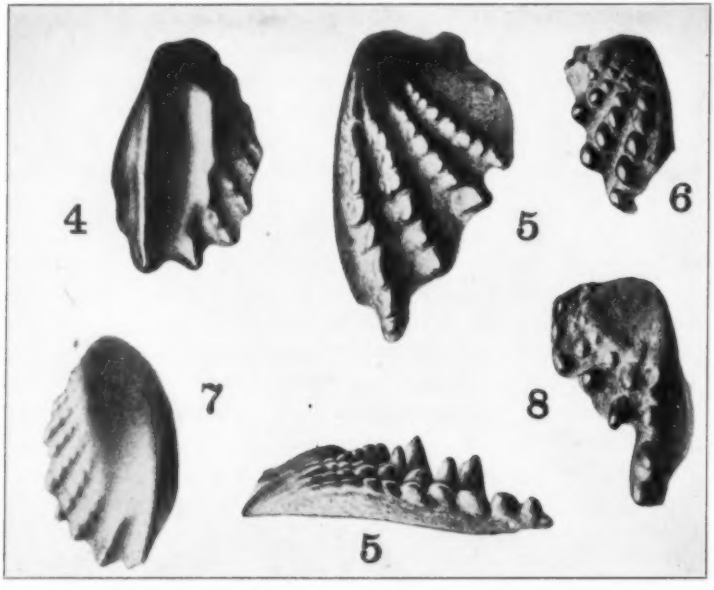

FIG. 4. *Dipterus costatus* sp. nov. Upper Devonian; Johnson county, Iowa.
FIGS. 5, 5¹. *Dipterus uddeni* sp. nov. Cedar Valley limestone; New Buffalo, Iowa.
FIGS. 6, 8. *Dipterus mordax* sp. nov. Upper Devonian; Johnson county, Iowa.
FIG. 7. *Dipterus calvini* sp. nov. Cedar Valley limestone; Fairport, Iowa.

whose honor the specific title is dedicated. A note of its geological occurrence was published in the August number of this JOURNAL (p. 494) for last year.

2. *D. calvini*, sp. nov. (Fig. 7).—Like the last, this species is founded on a unique dental plate (right mandibular) from the Cedar Valley limestone of Iowa. It comes from a higher level,

however, having been found by Professor Udden in the so-called "Euomphalus bed" at Fairport, Muscatine county, which lies about eight feet below the summit of the Cedar Valley limestone, or Hamilton of Worthen and others.

The plate is elliptical in outline, and moderately convex in an antero-posterior direction. Eight tuberculated ridges extend from the outer margin to about the center of the plate, the two anterior ones being the largest and elevated into a slight fold. Coronal surface considerably worn, and external margin partially broken. Tubercles conical and well separated, except those of the two anterior ridges, which are coalesced and worn on their summits. Total length of plate 3^{cm}. Named in honor of Professor Samuel Calvin, State Geologist of Iowa.

3. *D. costatus*, sp. nov. (Fig. 4).—This plate agrees in size and general outline with *D. calvini*, but it has fewer and more widely separated coronal ridges which disappear before reaching the center of the plate. The distinguishing feature of this species consists in the elevated sharp ridge extending along the entire length of the inner margin, and separated from the remaining tuberculated ridges by a broad longitudinal furrow. This ridge appears to be of compound origin, or made up of three coalesced costae, of which the third counting from the inner margin is the largest. The two innermost costae are so faint as to be almost imperceptible on the steep face of the main ridge. The summit of the latter is sharp, and shows no evidence of being made up of tubercles. The tubercles of the five marginal ridges are also worn nearly smooth and more or less coalesced. But for the convexity (in a longitudinal direction) of the coronal surface this might be taken for an upper dental plate. Several examples of this form have been obtained from the State Quarry fish-bed near North Liberty, in Johnson county, Iowa.

4. *D. mordax*, sp. nov. (Figs. 6, 8).—Dental plate attaining a length of over 3^{cm}, coronal surface gently convex, with six rows of very large, well separated conical or rounded tubercles which extend from the outer margin for a variable distance

toward the posterior angle; the two posterior rows often rudimentary. Some of the tubercles, when worn by use, become elongated in the direction of the rows to which they belong, and others in an oblique direction. This species is readily distinguished from all others previously described by the relative coarseness of its tuberculation. It is represented by a number of examples from the State Quarry beds of Johnson county, Iowa.

NOTICE OF PROBLEMATICAL ORGANISMS

Some thirty years ago Mr. Orestes St. John, when assistant in the Museum of Comparative Zoölogy, collected a number of Selachian teeth and spines and some large Dinichthyid plates from a "fish-bed" near Burlington, Iowa, supposed to be near the dividing line between Upper Devonian and typical Kinderhook. Small spines of *Stethacanthus*, *Erismacanthus*, and *Homacanthus* are rather abundant at this locality, also dermal tubercles of sharks. From the upper part of the formation Mr. St. John obtained the carapace of a Schizopod crustacean, and also some vegetable remains, such as branches of a Lepidodendron and woody fibers. In addition he found a number of peculiar fossils of which the one shown in Fig. 2 is a fair example, and within the past year other specimens of the same sort have been collected by Professor Udden in the Kinderhook near Burlington.

An examination of the latter forms by Professor Arthur Hollick of Columbia College leads him to the opinion that they are cone-scales of some conifer probably allied to *Araucaria*. A figure is given herewith for the benefit of those interested in the study of Mississippian faunas.

EXPLANATION OF FIGURES

FIG. 1. *Dinichthys pustulosus* E. Hamilton limestone; Milwaukee, Wisconsin. Left ramus of mandible. × $\frac{2}{3}$.

FIG. 2. *Cladodus monroei* sp. nov. Hamilton limestone; Milwaukee, Wisconsin. × $\frac{3}{4}$.

FIG. 3. Supposed cone-scale from Kinderhook fish-bed at Burlington, Iowa. × $\frac{3}{4}$.

FIG. 4. *Dipterus costatus* sp. nov. Upper Devonian; Johnson county, Iowa. Left lower dental plate.

FIGS. 5, 5[1]. *Dipterus uddeni* sp. nov. Cedar Valley limestone; New Buffalo, Iowa. Left lower dental plate, oval surface and profile.

FIG. 6, 8. *Dipterus mordax* sp. nov. Upper Devonian; Johnson county, Iowa. Somewhat worn examples of right lower dental plates.

FIG. 7. *Dipterus calvini* sp. nov. Cedar Valley limestone; Fairport, Iowa. Right lower dental plate.

[Figs. 4–8 reduced slightly less than natural size.]

C. R. EASTMAN.

ANCIENT ALPINE GLACIERS OF THE SIERRA COSTA MOUNTAINS IN CALIFORNIA

INTRODUCTION

NORTHWESTERN California is a vast complex of mountains, forming the Klamath system, whose geological features are similar to those of the Sierra Nevada range. Centrally situated within it is a series of high granitic and syenitic peaks, constituting the range of the Sierra Costa Mountains. Beginning in Castle Crag, about fifteen miles southwest of the lofty volcanic peak of Mt. Shasta, they trend thence southwestward about fifty miles, with an average width of between fifteen and twenty miles. Within this territory of eight or nine hundred square miles there are a score or more of bare, ragged peaks rising to altitudes of 7200 to 9345 feet above the sea. Between them are deep, narrow valleys whose floors have altitudes between 2500 and 6500 feet, averaging about 4000 feet. Some of the more elevated of these present distinct evidences of past glaciation. The glaciers were very localized in development, never coalescing to form a general glaciation of any part of the territory, and hence the glacial phenomena displayed in these mountain valleys are characteristically different from those of the drift-covered regions of the Mississippi basin.

GENERAL DESCRIPTION OF THE GLACIAL PHENOMENA

There is a radical difference in topography between the glaciated and non-glaciated valleys. The latter are V-shaped gulches with steep straight slopes and a width at the bottom often but little greater than that of the stream flowing within them. In places they are very rocky, with jagged ledges projecting from their sides. All the stony material found on their slopes is of the rock species underlying the soil on each particular slope. The same valley, traced up to where it once possessed a glacier, will rather abruptly change its form to a broad and

open U-shaped trough, with smooth and curved slopes, and a gently rounded floor. This change has been effected by a grinding away of the talus material and solid rock along the middle levels of the slopes and a filling of the extremely narrow lower portion of the gulch. The ravines have been destroyed, partly by filling and partly by the grinding away of the intervening ledges. Often this smoothing of the contours has extended up to a certain level, above which the mountain sides are deeply scored with ravines, and jagged with outcropping ledges.

Most of the valleys present but a moderate amount of ground-moraine, altho the lateral moraines are well developed. The glaciated slopes are abundantly supplied with bowlders of all the rock species occurring from thence to the head of the valley. They are embedded in a loose agglomeration of subangular gravel, sand and a little clay, forming a deposit quite unlike the till of the Mississippi basin, altho somewhat more nearly resembling the very stony moraines of New England. These lateral moraines are smooth in outline, rarely displaying a hummocky topography, and only in a few cases standing out distinct from the mountain ridges. In the unglaciated gulches, especially where the country rock is serpentine, extensive land slips are resting on the lower slopes, and they present a hummocky topography almost identical with that so characteristic of glacial moraines in the Mississippi basin, even to the extent of possessing kettle-holes containing lakelets. These must not be confounded with the lateral moraines.

Lines of erratics perched high on the mountain sides sometimes indicate the maximum altitude of the glacial action. From the smooth curved slopes of the lateral moraines, low narrow ridges of very stony material trend obliquely toward the center of the valley, those on opposite sides forming a loop, pointed downward. Sometimes they coalesce and are then cut by a small canyon-shaped valley thru which the stream finds an outlet from the enclosed basin above. These are the only representatives of true terminal moraines (being formed at successive

stages of readvance during the general recession of the glacier), but are quite insignificant as compared with the lateral moraines.

Near the heads of the glaciated valleys the rock surface is often bare over thousands of square feet, and is then seen to be smoothed and rounded by the grinding action of the ice. Some distinct grooves appear, but are not common. Of more frequent occurrence are fine lines or striæ, altho where long exposed these have been destroyed by weathering.

By far the most characteristic of the glacial phenomena of the Sierra Costa Mountains are the high meadows and lakelets. The former are smooth expanses of the valley floor a mile or more in length by half as great width, occurring near the heads of the valleys. They are inclined to be damp and boggy, and are grassed, instead of timbered and brushy, as other portions of the mountain region. They are underlaid with a fine gravelly silty ground moraine, and over their surfaces are frequently scattered large erratics of an englacial and superglacial mode of transportation. The lakelets are rounded bodies of clear cold water, varying from a fraction of an acre to twenty or more acres in extent, sometimes occupying rock-bound basins of glacial origin, but generally held in behind moraines. Around the border may be a tiny beach of white sand, or a narrow strip of flat, grassy land composed of black peaty soil. Some of these tiny mountain tarns are perched high up on the mountain sides in small coves or niches abraded from the solid rock by the downward pressure of the ice under the *névés*. A few of these coves are hundreds of feet in depth, have steep, often precipitous, rock-walls, and are nearly closed in by the surrounding ridges so that they closely resemble the *cirques* of the Alps.

An especially favorable situation for the glacial lakelets is at the foot of high rock precipices which usually occur on the southern or western sides of the valleys. The glaciers invariably hugged the shady side of the valleys and there accomplished their most active grinding work. It was on the northern side of the frowning peaks that the ice laid longest, and when its final melting

was accomplished, depressions were left at the foot of the precipices which had been produced by the removal of the talus material and some of the solid rock. In several cases one may stand on a high peak and throw a stone so that it will drop into the clear water of a lakelet, 1000 feet below. These high precipices are another characteristic of the glaciated valleys, for they never occur elsewhere in these California mountains.

The glaciers headed in valleys whose altitude is now between 6500 and 7500 feet above the sea, and descended to 5000 or 5500 feet (with two notable exceptions). Thus the declivity of the glaciated valleys is great; but the descent is effected by a series of terraces or steps, gentle slopes alternating with steep, almost precipitous, sections where the valley floor is rapidly let down 100, 200 or even as much as 500 feet vertically. These "steps" are only in small part due to moraines, being composed mainly of solid rock. Over them the glaciers cascaded, forming extensive crevasses, then coalescing into a solid mass and moving along smoothly a mile or more to the next cascade. Toward the close of the ice period, when the main glaciers had shrunk to insignificant remnants, tiny glaciers continued to issue from under the local *névés* in the coves high up on the mountain sides, and cascaded over precipices as much as 500 feet in height.

I have mentioned a sufficient number of the features of these valleys to place it beyond doubt that they have suffered glaciation in some past period, and to demonstrate that the glacial action was essentially identical in character with that at present obtaining in the high Alpine valleys of Switzerland.

CHARACTERISTIC FEATURES OF INDIVIDUAL GLACIERS

The Castle Creek glacier. — At its maximum extension, this glacier had a length of about two miles, a width of one quarter to one half mile and a depth of 500 to 800 feet. It was situated at the northern foot of Tamarack peak, near the junction between Trinity, Shasta and Siskiyou counties. The present altitude is about 6500 feet. Within the limits of its site are six pretty lakelets, one lying at the foot of a 1000-foot precipice. The glacier

flowed in an easterly direction and hugged the southern side of the valley, there leaving the rock bare of talus or morainic material. In receding, it melted away from the warm northern side of the valley, and left several successive lateral moraines on the valley floor, running lengthwise of it. The last of the series is about in the center. A trough shaped depression occupying the southern half of the valley indicates the final track of the dying glacier. In it lie some of the lakelets. A tributary glacier entered the main trunk at nearly a right angle, and cascaded over a rock-ledge now 500 feet above the main valley floor. The ledge is smoothed and striated. Above it a lakelet is held behind a moraine composed of clay, sand, gravel and bowlders, some of which are beautifully striated. The interesting feature of this glacier was its evident sensibility to the sun, causing it to melt away from the sunny side of the valley long before it disappeared from within the shadow of Tamarack peak.

The Salmon River glacier.—This was seven miles in length, one half to one mile in width and 1000 to 1500 feet in depth. Its course was a little east of north. It headed at about 6500 feet of altitude (present), and descended but little below 5500 feet. On the west of its upper half was the high granite peak of Mt. Courtney, whose slope is now bare of loose rocks and soil from summit to base and is worn smooth and rounded by glacial abrasion. From the precipitous pinnacles of the sawlike crest, huge bowlders of granite crashed down upon the ice, and now lie scattered upon the floor of the valley and even over the opposite slope. Several are as large as an average miner's cabin. Beyond the granite of Mt. Courtney, where the rocks are mainly hornblende and mica schists, the upper limit of the glacier is clearly defined high on the mountain sides by a sharp line below which granite bowlders are numerous and above which there are none; also, by shoulders or small precipices on the inter-ravine spurs of the mountain on the east, showing to what height the glacial abrasion extended.

Many prospectors and semi-scientific observers have noted the fact that the upper four or five miles of the original main

Coffee Creek has been beheaded and added to the South Fork of Salmon River, but not many have clearly discerned that this was due to glacial action. In ascending the Upper Coffee Creek valley, after the great bend is passed, the floor widens to quite a plain, there being here a heavy filling of waterlaid gravel and sand, the extra-glacial deposit of the glacier above; on this, at the mouth of each tributary gulch, there is a beautiful alluvial fan. About one and one half miles below the head of the creek, a slight ridge crossing the valley and carrying granite erratics marks the extreme limit of the glacier. From here to the summit stretches the "Big Flat," a smooth plain of fine gravel and sand (with scattered granite erratics) about one and one half miles in length and one half mile in width. At its upper end (which is the summit of the Sierra Costa Mountains, the water-parting between the main Klamath and the Trinity River systems, and the Trinity-Siskiyou county line) there is the slightest tendency to a morainic character. This "Big Flat" has an altitude of 5500 feet while the mountains on either hand rise to 7000 and 7500 feet. Here the glacier made a filling several hundred feet in thickness, thus obstructing the valley. At the same time it wore the rock wall of the valley on the west (which had already been nearly cut thru by the head water erosion of the original South Fork of Salmon River) so thin that a glacial stream crossed the ridge in a col and soon cut down a gorge. Hence it is that the South Fork of Salmon River rises in the head of the original Coffee Creek valley, follows it for four or five miles until within a few hundred yards of the present head of Coffee Creek, then turns to the west at a right angle, and passing out of the broad valley thru a narrow gorge where it abounds in rapids and falls, it makes its way thru unglaciated gulches to the Klamath. This is one of the finest examples of the beheading of a stream by glacial action that I know of.

As indicated by the granite erratics, the surface of this Salmon River glacier descended 1000 feet (and the glacier thinned to that amount) in the last one and one half miles of its course.

Within several miles of its head, the South Fork of the Salmon River has carved a pretty postglacial gorge or tiny canyon in the solid rock of the old valley floor. This is twenty to thirty feet in depth, has precipitous walls, and is no wider than the small stream flowing in it. It abounds in rapids and low cascades.

The Union Creek glacier.—This occupied the next main series of high valleys to the east of the Salmon River glacier. There was a main trunk five miles in length, and two branches each several miles in length. The width was one quarter to one half mile, and the thickness of all approximated 1000 feet. They headed at about 6500 feet (present altitude), and the main trunk descended to 5000 feet of altitude. Near its end it was much contracted, and but little modified the original V shape of the valley. Its extent is clearly defined by its very bowldery lateral moraines. One of these partly obstructs the mouth of a tributary valley, that of Pin Creek, which was not glaciated, altho equally as elevated as glacier occupied valleys on either side of it. This was because it opened too directly toward the sun.

When recession had proceeded to the extent of dissevering the branches of the glacier in the East and West Union Valleys, that of the East Union was the most vigorous, and formed a beautiful half-looped terminal moraine at the junction. The West Union Creek flows swiftly in a shallow ditch cut into the very bowldery deposit just outside of the crest of the moraine, but transverse to the general slope of the surface. This shows that this creek occupied its present course as early as the time when the moraine limited the East Union glacier. The extremely small amount of erosion accomplished on this steep declivity tells of the recency of the glacial epoch in these mountains.

The three Unions have the usual meadows, and are well supplied with glacial lakelets.

The Swift Creek glacier.—The characteristic features of this member of the glacial series were its length, its descent to a low

altitude, its heavy ground moraine, and its beautiful terminal moraine.

At its maximum extension, this glacier had a length of not less than fifteen miles, a width of one half to one mile, and a depth of 1000 to 1500 feet. It was the largest single mass of ice, so far as I know, of the Sierra Costa Mountains. It headed among the peaks in the highest portion of this range, at an altitude now about 6500 feet, trended in an easterly direction, forming the broad flat of the Mumford meadows (altitude 5500 feet), then ran southeasterly, descending rapidly to a level now little more than 3500 feet above the sea, where at ten miles from its head, it suddenly issued from the high mountains, and turning to the northeast, it deployed upon and across a broad basin valley of Miocene age and later, and terminated very close to the site of the Redding and Trinity Centre road at an elevation now no greater than 2500 feet above the sea. Here are, so far as I am aware, the least elevated direct glacial deposits west of the Sacramento River, if not in the whole state of California.

Among the prospectors of northern California, the "cemented gravel of Swift Creek" is a term to conjure with. It is essentially non-gold-bearing, and so far as the ability of the average miner to sink a shaft through it is concerned, it is bottomless. It is an unstratified agglomeration of bowlders, cobbles, pebbles, sand, silt, and clay, which occupies the valley from head to mouth, forms the flats or meadows, and is trenched by a narrow canyon carved by Swift Creek in postglacial time. Where the stream, in undermining a bank, has made a recent excavation, the deposit has an extremely fresh appearance and a delicate light bluish tint. Many of the included bowlders are rounded and polished, and not a few are beautifully striated. It is as typical a till as any to be found on this continent. Being largely the result of glacial abrasion on the rock floor and walls of the valley (serpentine mainly), it is slightly cemented by the large constituent of unoxidized magnesian and calcareous salts. Most of the included rock fragments are serpentine of the black

amorphose variety, and the light oil-green schistose variety, and the blue tinting was derived from the grinding of this formation. It cannot be worked for its included gold as a placer deposit, because there has been no concentration of the precious metal by water action as in ordinary stream alluvium.

This fine deposit of subglacial till or ground moraine attains its fullest development about midway of the course of the glacier where it must have a depth in places of not less than several hundred feet. At an altitude of about 5000 feet, the most prominent glacial features cease. Beyond this the valley contracts and descends rapidly over a series of high steps, which are strewn with a profusion of bowlders, some of which are striated. Everything here is confusion — there may be indistinct terminal moraines, lateral ridges, *roches moutones*, and some ground moraine, but the best expert cannot get much regularity out of the piles of bowlders heterogeneously distributed along the slopes of the bounding mountains and on the irregular valley floor. Here the creek descends rapidly in one long series of rapids and cascades, along its bowlder strewn bed, and in one place has cut a beautiful gorge thru the solid serpentine rock. It is several hundred feet in length and thirty to fifty feet in depth, and no wider than the stream. With its perpendicular and even overhanging walls, it is a veritable canyon. It abounds in *remolinos* (pot-holes) whose mode of formation can plainly be seen, from the clearness of the water.

When the Swift Creek glacier issued from the deep valley in the high Sierra Costa Mountains and deployed across the Miocene basin, it did not spread out as an alluvial delta, but it maintained its narrowness to the end, five miles distant. Around this extra-montane portion it formed a beautiful moraine. The constitution of this is essentially similar to that of the cemented gravel farther up the creek, except that it contains less clay, is looser and coarser in texture, and has some large erratics on its surface. Where trenched by tributary creeks and its interior freshly exposed, polished and striated pebbles and bowlders are not difficult to find. Two parallel ridges of about equal height,

and even crests, trend from the sides of the mouth of the upper valley northeastwardly across the Miocene basin, gradually descending toward Trinity River. Between them is a flat-bottomed, steep sided depressed area, 300 to 500 feet in depth and one half mile in width, evidently representing the cross-section of the glacial tongue. From the crests of the ridges more gentle slopes of very bowldery land extend outward and gradually merge with the erosion surface. These ridges are the extra-montane extensions of the lateral moraine, but also contain ground moraine and may be considered a terminal moraine. Near the Trinity River they flatten down, become hummocky and indistinct, but appear to curve around the end of the site of the ancient glacier and connect, except for the postglacial canyon which the stream has cut thru the moraine. Beyond this is a fine example of a fan-shaped extra-glacial delta, which occupies several square miles in the valley of the Trinity River, and its outer edge descends almost to the level of that stream itself.

This glacial tongue reached the northern end of the low Minerva range of mountains, and built its moraine across the mouths of several of the gulches. These have been filled nearly to the level of the moraine summit by fine silts, and form extensive grassy flats composed of deep black soil free from pebbles. Along the moraine the flats have some large angular erratics on their surface; these have slidden from the surface of the glacier.

In the bottom of the depressed area within the moraine Swift Creek has eroded a canyon 75 to 150 feet deep and 300 to 500 feet wide, widening and shallowing toward the mouth. This seems large, but represents glacial as well postglacial stream erosion.

On the whole, the glacial features of the Swift Creek valley are extremely interesting and instructive, and, from its accessibility, should become classical among students of California Quaternary geology.

The East Fork glacier.—This occupied a high valley, steeply descending on the east face of Granite Peak, a few miles northwest of Minersville. Near its head a precipitous mountain side

shows the smoothing and rounding action of the glacier up to a certain height, above which the bare rock is extremely rough and jagged. Some glacial grooves are seen and a little striation. In another place there is a well-defined line of perched erratics.

This glacier also issued from the high mountains, and it cut directly thru the old Miocene river channel, carrying its huge granite bowlders nearly or quite to the Minersville-Trinity Centre road, terminating at a point probably now no greater than 3000 feet of altitude. It is a well-known fact that all the gulches which are cut into this old Miocene channel deposit have been rich in placer gold, except the valley of the East Fork, which cuts directly thru it, and yet never paid to work. The apparent anomaly is explained when it is understood that the East Fork glacier ground all of the gold-bearing alluvium out of the valley and left in its place its own only slightly auriferous deposit—the glaciated valleys are never worked as placers.

Quite a number of other valleys in the Sierra Costa Mountains were once occupied by glaciers. The presence of a number of lakes (as mapped) in the deep canyons south and east of Mt. Thompson of the granite Cariboo range seem to indicate that a cluster of them occupied that region. Probably a score or more existed in Trinity county alone; but the examples given in this paper are typical of them all, and will suffice for the purposes of the present study.

THE AGE OF THE GLACIERS

At one time I thought I had detected evidences of two glacial epochs in the Sierra Costa Mountains, one very recent and another much older, but I have had to revise this opinion. The deposits near the lower end of the glaciated valleys are of slightly more aged appearance than those near the heads, but the contrast is not great. They are essentially a unit, so far as age is concerned.

The weathering of the once striated, polished, and perfectly smoothed rock surface, the erosion of small canyons in the rock-floors of several of the glaciated valleys near their heads, and

the peaty accumulations about the borders and on the bottoms of the lakelets show that the glaciation has not just terminated—the ice has been completely gone for at least several thousand years. Yet the many lakelets held behind frail barriers of till, the cascades and rapids, and the generally uneroded condition of the drift tell, in unmistakable terms, of the comparative recency, geologically speaking, of the glaciation. Subaerial erosion, aside from one main stream channel in each valley, has been practically nothing. Even the excavation of the single central canyon was largely accomplished while the ice yet lingered in the heads of the valleys, and by its rapid melting greatly increased the streams. With the steep declivities and the heavy annual precipitation, it is remarkable how little erosion has been accomplished in northwestern California since the glacial epoch. Certain cemented river gravels in the valleys of the East Fork of Trinity River, the main Trinity River, and lower Coffee Creek, which represent the outflow from the glacier, rest upon the lowest bedrock in these valleys, and the canyons since excavated in them are quite insignificant. Glaciation was one of the very latest events in the northern California valleys. That it was of late Quaternary age requires no argument.

The beautiful sky-blue till of the Swift Creek valley has a freshness which may be likened unto that of the Wisconsin drift-sheet in the Mississippi basin, and oxidation of its surface portion has not proceeded to any greater depth. Indeed, the youthful appearance of the whole series of glacial phenomena is identical with that which has come to be associated in my mind with the Wisconsin drift sheet. I am certain that this Sierra Costa glaciation was not the age equivalent of the Iowan or any earlier drift sheet. I am equally as certain that the glaciers disappeared a sufficient length of time ago to carry the glaciation back to the Wisconsin epoch. If there were two Wisconsin glaciations in the Mississippi basin, as some glacialists seem inclined to conclude, this California glaciation represented the later. At any rate, the glaciers of the Sierra Costa Mountains certainly were of Wisconsin age.

DISCUSSION OF CLIMATIC CONDITIONS DURING GLACIATION

It goes without saying that it was cold and there was much snow. But under this heading I wish to argue that there was no difference in the *character* of the climate between that and now—merely a lowered annual temperature and probable increased snowfall. The present climate of the Sierra Costa Mountains partakes of the general equability of the Pacific Coast region, but in addition possesses a typical alpine character. A strong contrast between the heat of night and day, *and between that of light and shadow*, is a characteristic of high altitudes where the atmosphere is clear and light, and radiation rapid. One may suffer from the heat in toiling up a sunny slope, while the air in the shadow of a peak may seem almost freezing cold. This is the condition of today at the higher levels of the Sierra Costa Mountains, and the behavior of the glaciers indicates that the same obtained in their time. They were unusually sensitive to sunlight, and shrank into the shadow of the peaks.

Gulches which faced the sun were unglaciated, altho perhaps surrounded by others in which ice accumulated to a depth of over 1000 feet. In fact, shadow was as much one of the necessary conditions of glaciation as cold and snow fall. This shows that the climate possessed the same alpine character as today. I am strongly impressed that the evidence indicates an altitude for these mountains during the Wisconsin epoch, at least as great as the present.

A POSSIBLE CAUSE OF THE GLACIAL PERIOD IN THE SIERRA COSTA MOUNTAINS

I am not prepared to argue conclusively as to why these glaciers formed in the elevated valleys of the northwestern California mountains; but I wish to present, in closing this paper, what I conceive to be a possible explanation of their existence, an hypothesis sufficient to account for all their phenomena.

The valleys where the ice accumulated are all above 6000 feet of altitude, and the sites of the main *névés* approximate a general elevation of 6500 feet above the sea. Even today the

climatic conditions at this altitude are not far removed from those favoring glaciation. The winter snow fall on the mountains is heavy, they being near the coast. On the higher peaks, light flurries of snow are often seen in July, and by the end of October, the winter's snow has set in in earnest. Storm after storm ensues thruout the winter and well on into the spring. By April 1 it is no uncommon thing for the higher mountains to be sheeted under eight, ten, fifteen, or in places as much as twenty feet in depth of well-packed snow. This melts away slowly. By June, most of it is gone; by July, nearly all; but some remains all the year on the northern slopes of Mt. Thompson and Granite Peak and in sheltered ravines of Mt. Courtney. This perennial snow lies at altitudes of about 8000 feet.

Now, in my opinion, a general uplift of the entire region to the extent of 3000 feet would be a sufficient cause for the duplication of the ancient glaciers and a restoration of the whole mountain range to its condition in the Wisconsin epoch. That would carry the summits of all the peaks above 10,000 feet, elevate the main ones, such as Granite Peak and Mt. Courtney, to 11,000 and 11,500 feet, and Mt. Thompson would tower to the altitude of 12,345 feet, comparable with Mt. Shasta. The heads of the glaciated valleys would be elevated to 9500 feet. If perennial snow lies today in small ravines at 8000 feet, how readily must it have accumulated in deep valleys over 1500 feet higher and in the shadow of peaks towering to 11,000 and 12,000 feet. Considerable bodies of snow lie all the year at no greater altitude on the sunny side of Mt. Shasta, and one may see snow on any summer day by glancing at Lassen Peak whose altitude does not much exceed 10,000 feet. Both these mountains are far from the coast, in a comparatively dry belt.

From their nearness to the Pacific Ocean, the elevated Sierra Costa Mountains must have received a heavier snow fall at a given altitude than Mt. Shasta. Also, being a group of mountains (acting like an elevated plateau) instead of a single isolated peak must have favored a lowering of the temperature and increased precipitation. Even without an added snow fall, a

simple elevation would not fall far short of reproducing the glaciers. But as the result of the uplift, it is safe to count on a greatly increased precipitation. It appears to me evident that the present conservative estimated average for the higher regions of ten feet annually might be doubled. Of this amount one half, or ten feet in thickness, might melt from the surface of the *névés* during each summer (the sun finds difficulty in removing that amount even at present altitudes). The remaining ten feet might compact into one foot of ice. Were there no loss by outflow and melting at the end of the glacier, the accumulation of one foot of ice annually would reproduce the large Salmon River glacier in 1500 years.

But a large part of the ice moved outward beyond the zone of accumulation and was lost by melting. This loss was partly compensated for by heavy snow-slides from the surrounding precipitous peaks; yet, with the greatest latitude, we must allow two or even three times as great a period as that first mentioned for the accumulation of the glacier, and the attainment of its maximum extent. I consider 5000 years as a fair estimate, and one which is not too strongly open to criticism. By a lowering of the altitude to the present and consequent increased mildness of the climate (in other words, a restoration of present climatic conditions), probably about half that time or 2500 years would be sufficient to cause the disappearance of the glaciers, and give time for the repeated slight readvances which marked their recession.

The preceding is intended merely as a suggestion, a hypothesis worthy of serious consideration. The demonstration of its reliability will depend upon external evidence of the supposed temporary uplift of these mountains. This can only be secured by careful geological work between this range and the sea, which has not yet been done.

The importance to glacialists in general of studies on the localized Quaternary glaciers of limited mountain districts lies not so much in the contrast between their alpine features and the continental features of the great North American and

European ice sheets, as in the bearing which they may have on the fascinating and yet unsettled question of the "Cause of the Glacial Period." After trying unsuccessfully to solve the problem through a study of the varied series of drift sheets in the Mississippi basin, I have concluded that we will do well to take into account such evidence as may be gathered in alpine regions of glaciation — outlines of the main sheets, we may say — for here the problem of determining climatic changes is less obscure. The suspicion is growing in my mind that the "Glacial Period" in geology, as a glacial or relatively cold epoch of time, was of world wide extent in its effects, and the absolute determination of the cause of the past accumulation of glacial ice in one section will be the key to the solution of the problem of all terrestrial glaciations.

OSCAR H. HERSHEY.

November 18, 1899.

AN ATTEMPT TO TEST THE NEBULAR HYPOTHESIS BY THE RELATIONS OF MASSES AND MOMENTA

In a paper entitled "A Group of Hypotheses Bearing on Climatic Changes,"[1] read before the Geological Section of the British Association for the Advancement of Science at the Toronto meeting in 1897, I assigned reasons for doubting the Laplacian hypothesis of the origin of the solar system, based on deductions from the kinetic theory of gases. These doubts had arisen in the course of certain atmospheric studies springing from the problem of ancient glaciation. The complete demonstration by the geologists of the far Orient that extensive ice sheets developed on the borders of the torrid zone in India, Australia and South Africa during a late stage of the Paleozoic era had made it imperative to seriously reconsider inherited views relative to the nature of the earth's early atmospheres, and this in turn forced an inquiry into the current postulate of a primitive, vast, gaseous envelope exceptionally rich in carbon dioxide; for the special heat-absorbing qualities of this constituent render it doubtful whether its presence in large amount is compatible with glaciation. The inquiry led to the application of such tests as could be derived from the doctrine of molecular velocities. As the result of such application it appeared quite impossible that a hot gaseous ring formed of the matter of the earth and moon, and having the dimensions postulated by the Laplacian hypothesis, could retain its water vapor and atmospheric gases, for its gravitative control over these was found to be far below what was necessary to overbalance their molecular velocities. It appeared very doubtful whether any of the matter of the ring, even that having the lowest molecular velocities, could be retained at the postulated temperatures and tenuity. The test seemed altogether decisive against the Laplacian hypothesis if the kinetic theory be true and the computed

[1] Published in full with supplementary tables in the Jour. Geol., Oct.–Nov., 1897, pp. 652–683.

molecular velocities essentially correct. However, the kinetic theory is perhaps not yet beyond its trial stages, though it is probable that the essential postulates involved in the doctrine of molecular velocities are true whatever the precise interpretation of the facts may be. There is an accord between the doctrine and the facts in the solar system which strengthens this conviction. There is an absence of atmosphere from all satellites and asteroids, so far as can be determined. The planet Mercury has little or no atmosphere. The small planet Mars has but a thin atmosphere. The Earth and Venus have considerable gaseous envelopes, while Jupiter and Saturn appear to have vast and deep atmospheres; in short, there is a general correspondence between the mass of the atmosphere and the gravitative competency of the body. In still further evidence is the essential absence of the lightest gases, hydrogen and helium, from the earth's atmosphere.[1] The former, to be sure, is chemically active, but the latter is very inert.

Notwithstanding the apparent strength of the molecular argument, other tests, based on quite independent grounds, are desirable. The more is this true since a modification of the form of the Laplacian hypothesis in which a lower temperature and a meteoroidal state are postulated deprives the molecular argument of much of its bearing. It is true that this change in the hypothesis when carried out consistently in its full application permits, if, indeed, it does not require, a revision of some of the fundamental doctrines of current geology, such as the former molten state of the earth and the long train of doctrines that hang upon this. So profound is the influence of this primal conception of a molten earth upon the dynamical conceptions and historical interpretations of the earth's evolution that every source of light bearing upon it has an importance we can scarcely realize at present.

[1] "On the Cause of the Absence of Hydrogen from the Earth's Atmosphere and of Air and Water from the Moon," by Dr. Johnstone Stoney, Royal Dublin Society, 1892. Also "Of Atmospheres upon Planets and Satellites," by the same, Trans. Roy. Dublin Society, Vol. VI, Part 13, Oct. 25, 1897; also "A Group of Hypotheses Bearing on Climatic Changes," by T. C. Chamberlin, JOUR. GEOL., Vol. V, No. 7, Oct.–Nov., 1897.

The laws of dynamics afford a firm ground of inquiry so far as they can be brought into service. As applied to mass and momentum they are rigorous, and so far as they can be covered by satisfactory computation they are decisive. The purpose of the present paper is to set forth the results of an attempt to apply these laws to the nebular hypothesis in certain ways that are more or less unfamiliar. These results are the outcome of a joint inquiry by Dr. F. R. Moulton and myself. They are a part of the results of a more or less continuous study on related themes lying on the border-land of geology and astronomy, running through the past three years. Our relations have been so intimate and our exchanges of ideas so free and so frequent that it is impossible to apportion the responsibility for the various methods adopted and the modes of carrying them out. The higher mathematical work is, however, to be credited to Dr. Moulton. It has perhaps been my function in the main to formulate problems and suggest general modes of attack, and Dr. Moulton's to devise methods of analysis and bring to bear the mathematical principles of dynamics, but this has not been uniformly so. Quite often we have proceeded by successive alternate steps in which each was the parent of its successor. In a paper in the *Astrophysical Journal* published essentially concurrently with this, by mutual understanding, Dr. Moulton discusses not only the bearings of the ratios of masses and momenta treated in this paper, but several other modes of testing the nebular hypothesis, some small part of which have been touched upon in my previous papers and some of which will be discussed in these pages later. The mathematical treatment of the present theme will be found in Dr. Moulton's paper.

For convenience and definiteness, the treatment here will be based on the Laplacian phase of the nebular hypothesis, but the conclusions will be found applicable, in all essential respects, to such meteoroidal modifications of the hypothesis as postulate a spheroidal form controlled by the laws of hydrodynamic equilibrium.

1. *Comparison of the moment of momentum of the nebular system with the moment of momentum of the present system.*—It is a firmly established law of mechanics that any system of particles of any kind whatever rotating about an axis retains a constant moment of momentum whatever changes of form or arrangement the matter may undergo by virtue of its own interaction. To make this law rigorously applicable to the solar system evolving along Laplacian lines, the influence of external and of incoming bodies must be excluded. Foreign meteoroidal matter has doubtless been added constantly to the system during its evolution, but the amount of this is assumed to be negligible; and if it were not, the law of probabilities would render its effect upon the rotation of the system an essentially balanced one, and hence immaterial. The following argument proceeds upon the Laplacian assumption that the system evolved through the operation of its own inherent dynamics. On this assumption the sum total of rotational and revolutionary momentum must have been the same at all stages of the system's evolution.

The following table gives the masses and the present moments of momenta of the several members of the solar system and of the whole system. They are taken from Darwin's paper, "On the Tidal Friction of a Planet attended by several Satellites and on the Evolution of the Solar System,"[1] and are employed in the subsequent computations. The masses assigned the planets embrace those of the attendant satellites.

Body	Masses (Earth 1)	Moments of Momenta (Darwin)
Sun	315,511.00000	.444 Laplace's density law (Min.) .679 Homogeneous density (Max.
Mercury	.06484	.00079
Venus	.78829	.01309
Earth	1.00000	.01720
Mars	.10199	.00253
Jupiter	301.09710	13.46900
Saturn	90.10480	5.45600
Uranus	14.34140	1.32300
Neptune	16.01580	1.80600
Solar System	315,934.51422	22.53161 (Min.) 22.76661 (Max.)

[1] Phil. Trans. Roy. Soc., Part II, 1881, pp. 516, 517.

The distribution of density in the sun is unknown. If it follows Laplace's law the rotatory momentum is .444. If it be regarded as homogeneous, the rotatory momentum is .679. This latter is certainly too large, and the former number is probably much nearer the truth, but the larger number is used in the greater part of the computations because it is more favorable to the Laplacian hypothesis.

To obtain the rotatory momentum of the ancestral nebula it is necessary to consider its form, extent, and the variation of its internal density. By hypothesis the form was an oblate spheroid, but the exact degree of polar flattening is unassigned. Simple inspection, as well as mathematical analysis, shows that a given mass of matter rotating as a sphere will have a less moment of momentum than when it takes the form of an oblate spheroid, the time of rotation and other factors being equal. If a yielding sphere be rotated it takes the spheroidal shape because that is the form of equilibrium for the added rotational momentum, and is an expression of such addition. To give the Laplacian hypothesis the benefit of every doubt, the moment of momentum of the nebula is computed on the basis of a sphere. So also to favor the hypothesis, the nebula is made to reach merely *to* the orbit of the derived planet, not to extend beyond it as is usually and necessarily assumed. In computing the rotatory momentum of the whole nebular mass just before Neptune was separated, it is assumed that it reached only to Neptune's orbit, whereas the nebular border must probably have extended some 500 million miles beyond.

As this question of the distribution of the matter from which the planets were formed under the Laplacian hypothesis has other applications, it may be remarked here that in the formation of a planet from a ring of dispersed matter the planet must assume such a point within the ring as to preserve the moment of momentum of the mass. In a symmetrical ring this point is somewhere near the center of the cross section. Though subject to some qualifications from the greater circumference of the outer part and the possibly greater density of the inner part

and other contingencies, it will be sufficiently accurate for the purposes of this discussion to assume that the planets were formed in the centers of their respective rings, and that the space appropriate to each planet reached half way to the neighboring planets.

The more important consideration, however, in determining the rotatory momentum of the ancestral nebula is the distribution of its internal density. Our method has been to compute this on the basis of the recognized laws, using in particular the formula of Lane, and to compare results with the previous determinations of mathematicians and physicists.[1]

The distribution of density in such a nebulous sphere has been the subject of investigation by Lane, Ritter, G. W. Hill, George Darwin, Lord Kelvin, and others.[2] The results reached by all are in substantial agreement, though somewhat different analytical methods were followed. In obtaining the final numerical results used in this paper, the distribution of density found by Darwin was adopted. The method of computation is given in Dr. Moulton's paper in the *Astrophysical Journal.*

When the solar nebula extended to the orbit of Neptune and embraced the matter of the whole system and had a rotation

[1] The laborious work of making the computation was undertaken by Mr. C. F. Tolman, Jr., under the direction of Dr. Moulton, and preliminary results were obtained by him, but before these had been sufficiently verified he was called to a position whose immediate requirements prevented the completion of the desired verification. For this reason, and for the obvious advantage of resting the present argument as far as possible on the computations of an acknowledged authority, results reached by Darwin, which are applicable to a gaseous or meteoroidal nebula in convective equilibrium, have been adopted.

[2] LANE: On the Theoretical Temperature of the Sun under the Hypothesis of a Gaseous Mass Maintaining its Volume by its Internal Heat, and Depending on the Laws of Gases as Known to Terrestrial Experiments, Am. Jour. Sci., Vol. XLIX, pp. 56–74, 1870.

RITTER: Untersuchen über die Höhe der Atmosphäre und die Constitution gasförmiges Weltkoper, Wiedemann's Annalen (New Series), Vol. XVI, 1882, p. 166.

G. W. HILL: Annals of Mathematics, Vol. IV, 1888.

DARWIN: On the Mechanical Condition of a Swarm of Meteorites, and on the Theories of Cosmogony, Trans. Phil. Soc., 1888.

KELVIN: On the Origin and Total Amount of the Sun's Heat, Popular Lectures and Addresses, 1891. Constitution of Matter, pp. 370–429.

equal to the angular velocity of Neptune, its computed moment of momentum was 4848.055, while the present moment of momentum is 22.7666. The unit is an arbitrary one arising from the selection of convenient initial units. In this paper, Moulton's unit is converted into Darwin's unit, for convenience of comparison. It appears, therefore, that notwithstanding the concessions to the Laplacian hypothesis by which the present moment of momentum was made too large, and the nebular moment of momentum too small, the latter is still 213 times larger than the former. The dynamical law that demands constancy of moment of momentum is not even remotely fulfilled. A more rigorous computation, following the probabilities of the case without regard to its bearings on the Laplacian hypothesis, would increase the discrepancy.

Individual discrepancies.—Not only does the law fail of realization when the present system taken as a whole is compared with the ancestral nebula, but also in a comparison between the successive nebular stages and the corresponding parts of the present system. For example, the computed rotatory momentum when the nebula extended to Jupiter's orbit, and included the Jovian mass, was 1996.420, while the moment of momentum of the present system, minus the moment of momentum of Neptune, Uranus, and Saturn, is 14.1816. The discrepancy here is more than 140 to 1.

When the nebula extended to the earth's orbit, and included the terrestial mass, its moment of momentum was 857.330. The moment of momentum of the Earth, Venus, Mercury, and the sun, by hypothesis formed from this nebula, is only .71008. In this case the excessive estimate of the sun's moment of momentum, due to the assumption of homogeneity, introduces a disproportionately large error, and yet the discrepancy is 1208 to 1. Computing the sun's moment of momentum on the basis of Laplace's law of destiny, the discrepancy is 1801 to 1.

When the nebula extended to Mercury's orbit, and included this planet's mass, its moment of momentum was 512.290, while the moment of momentum of Mercury and the sun (excessively

estimated) is 0.67979, making the discrepancy 754 to 1. On the more probable basis of Laplacian solar density the difference is 1127 to 1.

From these data it appears that there is not only a fundamental and pervasive discrepancy between the computed nebular momentum and the actual present momentum, but there is also a strange irregularity in the discrepancies themselves. A fundamental error in the analytical work, or in the assumptions on which it is based, should give a systematic error, or at least a graded series of errors. But the discrepancy shown is not systematic or even graded. Not only are the discrepancies enormously large in themselves, but their irregularities are also large. This will appear better by bringing them together into a table.

Nebular M. of M.	Present M. of M.	Ratios.
Neptunian stage, 4848.055.....	22.76661	213 to 1
Jovian " 1996.420.....	14.18161	141 to 1
Terrestial " 857.330.....	0.71008	1208 to 1
Mercurial " 512.290.....	0.67979	754 to 1

2. *Can these discrepancies be due to a radical error in the law of density?*—It is certain that Boyle's law is not rigorously applicable to gases under all conditions, and it is pertinent to inquire whether any deviation from it can account for the discrepancies which the foregoing computations reveal. The researches of Amagat[1] and others have shown the nature of the deviations within the limits of experimental tests and Van der Waals' law furnishes a basis for the theoretical extension of these results to other conditions.

Near the temperatures of liquefaction the density increases faster than the law requires. Obviously the exterior of the nebula would be effected by lower temperature than its interior and would be most influenced by this variation so far as dependent on low temperatures. As the peripheral portion carries the largest part of the rotatory momentum any increased density there through failure of Boyle's law would increase the discrepancy.

[1] WÜLLNER: Experimental Physik. Tables. Vol. I, p. 542.

In the interior of the nebula the temperatures were probably far above the critical temperatures of all known substances, and this renders it improbable that central liquefaction prevailed during the nebular stages; indeed the very dispersion of the matter into so vast a volume as the Laplacian hypothesis postulates may perhaps be taken as an implicit assertion of the dominance of the gaseous laws throughout the mass. This is certainly the view of its ablest exponents. Lord Kelvin speaking of a globular gaseous nebula (selected to represent the primitive nebula), having the mass of the solar system and a radius forty times the radius of the earth's orbit, says: "The density in its central regions, sensibly uniform throughout several million kilometers, is one twenty-thousand millionth of that of water; or one twenty-five millionth of that of air."[1] Similar determinations may be found in the more elaborate computations of Darwin for varying dimensions of the nebula.[2] We are therefore apparently not dealing with densities, even in the central parts, greater than those covered by experimental evidence.

Besides, the present distribution of matter in the solar system offers an independent argument against any great central liquefaction, until after the earth was separated at least, for, by hypothesis, the earth was formed from the extreme equatorial periphery of the nebula, but the larger part of its material is of the most refractory kinds known and would pass into the liquid and solid states early in the history of condensation. There seems little ground therefore for assuming any effective condensation of the central matter of the nebula during at least the early stages of planetary evolution.

On the other hand, experimental evidence and theoretical deductions alike indicate that under very high pressures, where the temperature is also above the critical point, the density fails to increase as fast as the pressure. As these are the assigned conditions of the central part of the nebula, any failure of the law in this direction would increase the discrepancy.

[1] Popular Lectures and Addresses, I. Constitution of Matter, p. 419.

[2] On the Mechanical Conditions of Swarms of Meteorites, and on Theories of Cosmogony, Phil. Trans. Roy. Soc., 1888.

It does not appear therefore that there are good grounds for assuming a failure of the recognized law of density in such a direction as to relieve the great discrepancy shown by the computations. In any case there is the gravest reason to doubt whether it could reach a value represented by a multiplier ranging from 140 to 1200, not to say 1800.

But even if an arbitrary attempt were made to reduce the computed moments of momenta to consistency with those of the existing system, it is not apparent how it could be attended with success and preserve self consistency. The discrepancies are:

For the Neptunian nebula - - - -	213 to 1
For the Jovian " - - - - -	141 to 1
For the Terrestial " - - - - -	1208 to 1
(or on the more probable basis) - -	1801 to 1
For the Mercurial nebula - - - -	754 to 1
(or on the more probable basis) - -	1127 to 1

Now any deviation from the recognized law must be supposed to be consistent for analogous conditions. If therefore we assume such a modification as to bring the moment of momentum of the Neptunian nebula into equality with the present moment of momentum, we must assume that a similar modification held good for all the subsequent stages, either in the same proportion or in some systematically increasing or decreasing proportion. But the ratios succeed each other in a very arbitrary way, and the Neptunian divisor will not bring the others into accord, nor will any obvious series of divisors built systematically upon it. Were the computation extended to the other nebulæ, additional irreducible irregularities would doubtless appear.

3. *The ratio of masses to momenta.*—In the symmetrical evolution of a spheroidal nebula by secular cooling, as postulated in the Laplacian hypothesis, it is reasonable, if not necessary, to suppose there would be some systematic and rational relationship between the masses separated from time to time and the moments of momenta of these masses, for the separation was due to a common progressive cause, the acceleration of rotation. The hypothesis may therefore be tested along these lines. In

the test here applied the question of nebular density does not enter, and certain assumptions that might be made to meet the previous discrepancies are here checked.

Just previous to the hypothetical separation of the Jovian ring from the solar nebula the moment of momentum of the latter, reckoned from the present momenta of its derivatives, was 14.1816, if the sun be regarded as homogeneous, or 13.947, if the sun's density followed Laplace's law which is probably much nearer the truth. Of this, Jupiter now has 13.469. Neglecting for the present subsequent transfers of momentum, it follows that when the Jovian ring separated it carried away 13.469 / 14.182 or about 95 per cent. (94.97 per cent.) of the total moment of momentum of the nebula (or 96.57 per cent. on the more probable basis). Now the mass of Jupiter's ring was 1 / 1049 of the parent nebula, or less than one tenth of 1 per cent. It thus appears that the unqualified Laplacian hypothesis involves the implicit assertion that in the formation of the Jovian ring less than one thousandth of the mass carried away 95 per cent. of the moment of momentum. Is this possible in a spheroid of gaseous or quasi-gaseous material in convective equilibrium? One nineteen-thousandth more of the mass thrown off with an equal proportion of rotational momentum would have exhausted the supply. Apparently the minor planets had a narrow escape from not being at all.

Similar but not uniform disparities appear in a comparison of the masses and momenta of the other planetary rings with their parent nebulæ. In such a comparison also the great disparities in the planetary masses become conspicuous.

The mass of the Neptunian ring was about five thousandths of 1 per cent. of its nebula and by hypothesis it carried away about 8 per cent. of the moment of momentum of the nebula.

The mass of the Uranian ring was four and a half thousandths of 1 per cent. of its nebula. It hypothetically carried away 6 per cent. of the nebular moment of momentum.

The mass of the Saturnian ring was less than a third of a hundredth of 1 per cent. of its nebula and yet it carried away 27 per cent. of the nebular moment of momentum.

The mass of the Martian ring was three hundred-thousandths of 1 per cent. of its nebula, and yet it took away 0.35 per cent. of the moment of momentum of the nebula.

The mass of the Terrestrial ring was less than a third of a thousandth of 1 per cent. of its nebula, and it carried away 2.4 per cent. of the nebular moment of momentum.

The mass of Venus' ring was about one fourth of a thousandth of 1 per cent. of its nebula, and it carried off 1.89 per cent. of the nebular moment of momentum.

The mass of the Mercurial ring was only about one fifth of a ten-thousandth of 1 per cent. of its nebula, and it hypothetically carried off 0.12 per cent. of the nebular moment of momentum.

Not only are these ratios very extraordinary in themselves, but their relations to each other seem scarcely less remarkable. This will appear more apparent when they are gathered into a table and referred to a common unit. This unit is one one-hundred-thousandth of 1 per cent of the individual nebular mass. It will be seen that on this *proportional* basis, the moments of momenta range through a gamut of more than ten points, the proportion of Mars being more than ten times that of its neighbor Jupiter.

Ring	Percentage of mass of its nebula	Percentage of M. of M.	Percentage of M. of M. reduced to basis of .00001% of nebular mass.
Neptunian	0.00507	7.93	.0156
Uranian	0.00454	6.31	.0139
Saturnian	0.02852	27.78	.0098
Jovian	0.09530	94.97	.00996
Martian	0.0000323	0.36	.1099
Terrestrial	0.0003160	2.42	.0766
Venus	0.0002495	1.89	.0755
Mercurial	0.0000205	0.12	.0566

There seems to be no systematic variation in these. It is furthermore remarkable that, high as is the ratio of Jupiter's moment of momentum to the parent nebula, it is proportionately surpassed in most other cases.

4. *Can these high ratios of the moments of momenta of the planets to the residual nebulæ be attributed to transfer of moment of momentum*

from the sun by tidal friction?—Darwin has made familiar the principle of the transfer of the moment of momentum of a rotating body to its satellite by his classic investigation of the evolution of the earth-moon system. Applying this principle to the solar system, is it possible to explain the low rotatory momentum of the sun and the high moments of momenta of the planets by a transfer of momentum from the former to the latter?

The most obvious and tangible effect of solar tidal friction on the planets is to destroy their rotations. The patent fact that most of them still retain high speeds of rotation is a physical expression of the limitations of past tidal action.

Darwin has computed the rotational momenta of all the planets that afford the requisite data and also the revolutionary momenta of their satellites.[1] Making a generous allowance for the unknown and uncertain factors and counting in unnecessarily the orbital momenta of the satellites, the whole internal momentum of the planetary systems falls short of a thousandth part of the sun's rotational momentum computed on the minimum basis. This means that to have reduced the sun's rotational momentum from twice the present amount to the existing status, and to have transferred this to the planets, more than a thousand times the total rotatory momentum of all the planets must have been destroyed. But this would be only a slight step toward the adjustment contemplated.

To realize what might be necessary, if the foregoing nebular computations are well founded, let the matter of the solar system be converted into a gaseous nebula in hydrodynamic equilibrium extending beyond the orbit of Neptune; let this nebula be given the moment of momentum of the present solar system, and then let it contract by cooling, with the development of accelerated rotation, as postulated in the Laplacian hypothesis. An inspection of the foregoing data will show that the centrifugal force would not become equal to the centripetal force until the nebula had shrunk far within the orbit of Mercury. The

[1] On the Tidal Friction, etc., pp. 519–523.

tidal problem then becomes the dispersal of the planets from this central position to their present places.

Concerning the competency of the solar tides to alter the orbits of the planets (and hence their moments of momenta), Darwin says:[1] "It may be shown that the reaction of the tides raised in the sun by the planets must have had a very small influence in changing the dimensions of the planetary orbits around the sun. From a consideration of numerical data with regard to the solar system and the planetary subsystems, it appears improbable that the planetary orbits have been sensibly enlarged by tidal friction since the origin of the several planets." Again, he says:[2] "If the whole of the momentum of Jupiter and his satellites were destroyed by solar tidal friction, the mean distance of Jupiter from the sun would only be increased by one twenty-five hundredth part. The effect of the destruction of the internal momentum of any of the other planets would be very much less." And again:[3] "The present investigation shows, in confirmation of preceding ones, that at this origin of the moon the earth had a period of revolution about the sun shorter than at the present by perhaps only a minute or two, and it also shows that since the terrestrial planet itself first had a separate existence the length of the year can have increased but very little, almost certainly by not so much as an hour, and probably by not more than five minutes."

Aside from the quantitative difficulties there are formidable qualitative ones growing out of the proportional distances of the planets and the enormous lapses of time involved in a tidal retrogression of the planets through the postulated distances.

Conclusions.—The general result of the inquiry is to show, if we have not somewhere fallen into error, various relationships of mass and momentum which are seemingly altogether incompatible with an evolution of the solar system from a gaseous spheroid controlled by the laws of hydrodynamic equilibrium

[1] Encyclopedia Brittanica, Article "Tides," p. 380.

[2] On the Tidal Friction, etc., p. 524.

[3] Loc. cit., p. 533.

and developing by secular cooling. The argument is equally cogent against an evolution from a meteoroidal spheroid controlled by the laws of convective equilibrium, such, for example, as that made the subject of investigation by Darwin in his memoir: "On the Mechanical Conditions of a Swarm of Meteorites and on Theories of Cosmogony."

The results point to an unsymmetrical distribution of matter and of momentum. It should go without saying that we assume a nebular origin in the broad sense of the term, but the inquiry seems to show that the original form of the nebula and the mode of its development are to be sought on new lines. The foregoing data seem to constitute criteria of a rather rigorous nature to which a working hypothesis must conform. They are thereby aids in the construction of a tenable hypothesis. They seem to require the assignment of some mode of origin by which the peripheral portion of the system acquired all but a trivial part of the moment of momentum, while it possessed but a trivial part of the mass. The first suggestion of these conclusions was the possible formation of the system by the collision of a small nebula upon the outer portion of a large one, the smaller one having necessarily a high ratio of momentum to mass, while the larger one may have had little or no rotatory momentum, or even an adverse rotation. The low degrees of ellipticity of the present orbits seem to present grave difficulties in the framing of a consistent hypothesis of origin along this line, but these may not prove insuperable.

The results also naturally turn thought anew toward existing nebula for an exemplification of the evolution of the solar system. It is not a little significant that of the thousands of nebula now known no one, I believe, closely represents the annular process; certainly none represents the secondary annulation coincident with the primary. To bring the current hypothesis into consistency with observed nebular states, it seems necessary to assign it to so late a stage of concentration and to such small dimensions as to be beyond observation—at most, a hypothetical resort.

Following a purely naturalistic and inductive method, it would seem that the spiral nebulæ, whose abundance is attested by the recent notable success of Professor Keeler in photographing numerous small ones, offer the greatest inherent presumption of being the ancestral form. While present knowledge of their dynamics is almost inappreciable, the suggestions of their forms and the distribution of their matter do not seem necessarily incompatible with the criteria deduced in this inquiry.

Both these suggestions are obviously very immature, and have their sole justification in a natural reluctance to offer destructive results only—a reluctance intensified by an acute consciousness that the hypothesis against which they are directed is perhaps the most beautiful and fascinating ever offered to the scientific public.

T. C. Chamberlin.

EDITORIAL

FOR more than thirty years Mr. W. F. E. Gurley, of Danville, Illinois, formerly the official geologist of this state, has been one of the most systematic collectors of Paleozoic fossils in the Mississippi valley. Not only has he gathered together what is probably the best existing collection of Paleozoic fossils of the interior states, but he has secured a large amount of valuable material from other portions of this country and from Europe. The collection has furnished much material for study to such paleontologists as C. A. White, E. D. Cope, S. H. Scudder, J. S. Newberry, Leo Lesquereaux, and Charles Wachsmüth, and many types of the species described by these men are included in it. More recently Mr. Gurley himself, associated with the late S. A. Miller, of Cincinnati, has described many new species from the collection. Aside from these types Mr. Gurley has been fortunate in securing many other types of species described by Owen and Shumard, Hall, Wetherby, and Miller.

In addition to the types in the collection, which are about 600 in number, some of its most noticeable features are the following: an exceptional series of Devonian fossils from the falls of the Ohio, including crinoids, corals, brachiopods, and trilobites; a fine series of Kinderhook crinoids from Le Grand, Iowa; an admirable series of Coal Measure crinoids from Kansas City, Missouri; a large collection of fish remains from the limestones of the Mississippi valley; an almost exclusive collection of the vertebrate remains from the Permian bone bed near Danville, Illinois, including all the types of the species from this locality described by Professor E. D. Cope; and a fine series of blastoids and cystoids. Among the foreign material a choice series of Solenhofen slate fossils and an excellent series of Carboniferous crinoids from Moscow, are worthy of special mention. These features serve to show something of the contents of the

collection, but they constitute only a small portion of the whole. The entire collection is estimated to contain 15,000 species and several hundred thousand specimens.

Through the generosity of Mr. Gurley himself, this collection has recently become the property of the University of Chicago. It will be installed in Walker Museum as rapidly as possible and will constitute the nucleus of still further growth. It will be the policy of the University to make this collection, and the future additions to it, not merely an exhibition of rare and choice fossils, but a basis of research which will be open to competent students under approved conditions. It will, beyond question, prove to be eminently serviceable in promoting appropriate lines of investigation and will thereby constitute a notable contribution to the progress of historical geology.

STUART WELLER.

Reviews

The Diuturnal Theory of the Earth; Or, Nature's System of Constructing a Stratified Physical World. By William Andrews. Published by Myra Andrews and Ernest G. Stevens. New York, 1899. 8vo, pp. 551.

The consideration that might naturally be awakened by the evidences of great labor under manifest limitations embodied in this posthumous book is well nigh forstalled by the bad taste and absurd presumption of the preface by Mr. Stevens in which Mr. Andrews is styled "the greatest scientist America has produced" who "left comparatively little to be accomplished," and so forth.

"The Diuturnal Theory of the Earth" consists essentially of the assumption that "the north terrestrial polar point is taken within 30° to the south siderial polar point, and returned to within 60° of the point under the north star, from whence it started," and that the essential features of geological history are due to this. This polar movement is assumed to have taken the form of a spiral migration involving "six polar transitions" across the eastern and western hemispheres. There is no serious attempt to show that such a movement was a fact either by inductive evidence or deductive theory. The author's method seems to have been the pre-scientific one of developing a conception essentially *ex nihilo* and of interpreting the phenomena by means of it. The book is interesting as an exhibition of great labor enthusiastically devoted to the broad themes of geology under limitations that precluded either the mastery of the facts needed for induction or the dynamic principles necessary for deduction. If the filial regard which has given it to the world a dozen years after the author's death had been content to rest it on the modest basis of the thoughtful efforts of a studious man working under conditions that precluded success, it would have been wiser than to put it forth with the pretentious assumption of having "made the patchwork of geology into a complete science."

T. C. C.

Memoirs of the Geological Survey of the United Kingdom. The Silurian Rocks of Britain. Vol. I, Scotland, 1899. By B. N. PEACH, JOHN HORNE, and J. J. H. TEALL.

This publication, which comprises the first volume of a proposed monograph on the Silurian rocks of Great Britain and Ireland, treats of the Silurian formations of Scotland in a praiseworthy degree of completeness. It is a work destined to maintain the high standard of excellence attained by the British Survey Reports.

The opening chapter is devoted to the physical features of the Silurian region. The region in general comprises the Southern Uplands which, lying between the Central Lowlands on the north and the Cheviot Hills and Solway Firth on the south, stretch from the North Sea to the Irish Channel. The topography of the region varies from the uniformly smooth or undulating types in the central and eastern parts to the rugged craggy type of the southwestern part. The Uplands vary in height from one to two thousand feet. The northern border is traversed by an extensive fault which lets down the Devonian and Carboniferous rocks of the north to form the surface of the Central Lowlands.

The succeeding chapter is devoted to the history of previous researches among the rocks of this district. These researches cover a period of more than a century, and have engaged the attention of many of Britain's foremost geologists of the past and present. Beginning with Hutton among others are the names of Hall, Fairplay, Nicol, Harkness, Murchison, Sedgwick, Ramsay, A. Geikie, J. Geikie, and Lapworth, besides the names of the authors, Peach, Horne, and Teall. To Lapworth is given the credit of establishing by paleontological and stratigraphical achievements the true order of succession of the Silurian strata. His studies of the sequence of the Silurian graptolite faunas made possible the correction of erroneous estimates of the thickness of the beds and enabled the structure of the region to be worked out in the most complicated areas.

The stratigraphy and the tectonic arrangement of the rocks are set forth in the third chapter of the volume. The Lower Silurian series is divided into the Arenig, the Llandeilo, and the Carodoc formations. The Arenig strata consist of cherts, mudstones, shales, and volcanic tuffs interbedded in places with tuffs, lavas, and agglomerates, associated with intrusive masses comprising serpentine, olivine, enstatite

rock, and gabbros. Many of the volcanic eruptions took place under submarine conditions. There were also periods of quiescence, during which fine sands and mud containing fossils were deposited.

A subsidence of the sea floor ushered in the next period, the Llandeilo. The rocks of this formation are radiolarian cherts and mudstones which were deposited in clearer waters than the rocks of the Arenig. The rocks of the Carodoc are shales, conglomerates, and limestones, implying variable conditions of deposition.

The Upper Silurian, it is said, is separated from the Lower Silurian by both physical and paleontological changes. But there appears to be no great paleontological break such as characterizes the separation of the Ordovician from the Silurian on the interior of the American continent. The transition from the Lower Silurian to the Upper Silurian types is a gradual one. This province may constitute one of harbors of refuge spoken of by Professor Chamberlin in his discussion of the source of provincial faunas. It would correspond, then, on the American continent, to the embayment at the mouth of the St. Lawrence. The following table will serve to compare the distribution of the Brachiopods common to the two countries, Scotland and America:

	Scotland		America	
	Lower Silurian	Upper Silurian	Ordovician	Silurian
Atrypa reticularis	x	x	..	x
Atrypa marginalis	x	..	..	x
Cyrtia exporrecta	..	x	..	x
Leptaena rhomboidalis	x	x	x	x
Plectambonites transversalis	x	x	..	x
Platystrophia biforata	x	x	x	x
Rafesinesquina alternata	x	..	x	..
Bilobites bilobus	x	x	..	x
Dalmanella elegantula	x	x	..	x
Dalmanella testudinaria	x	..	x	..
Orthis tricenaria	x	..	x	..
Pentamerus oblongus	..	x	..	x
Uncinulus stricklandi	x	..	..	x
Spirifer crispus	x	x	..	x
Spirifer radiatus	..	x	..	x
Rafesinesquina deltoidea	x	x	x	..
Rafesinesquina imbrex	x	..	x	..
Total of species	14	11	7	12

This table shows that of the fourteen species occurring in the Lower Silurian of Scotland but one half that number are represented in the American Ordovician, the other seven species appearing in the American Silurian. As most of these species occur in the last member of the Lower Silurian, the Carodoc, it is probable that this formation forms the transition zone between the Ordovician, as we know it, and the Silurian.

The Upper Silurian series is divided into the Llandovery, the Tarannon, the Wenlock, the Ludlow, and the Downtonian. These formations consist of mudstones, limestones, grits, graywackes, and conglomerates. The Downtonian which hitherto has not been recognized as a part of the Silurian is probably the equivalent of the Waterlime formation of our own country. It contains a fauna consisting of Ostracoids, Eurypterids, and fishes similar to the fauna of the Waterlime formation. This formation immediately underlies the Old Red Sandstone.

The economic products of the Silurian formations are lead, iron, copper, antimony, manganese, zinc, mispickel, silver, and gold, besides building materials, road-metal, and hone-stones.

Other chapters in the book are devoted to contact-metamorphism, and to the granites and associated igneous rocks.

W. N. LOGAN.

Genesis of Worlds. By J. H. HOBART BENNETT. Springfield, Ill.: H. W. Rokker, printer, 1900. Pp. 345.

This work does not need serious review from the point of view of science. It is the product of a mind deeply interested in the problems of cosmogony and apparently ready to accept the demonstrations of science, but yet still under the dominance of the traditional anthrophic mode of thought. It betrays throughout a serious lack of firm grounding in the elements of the sciences involved in the subjects under discussion, a grounding absolutely necessary to their successful treatment. The mode and style of the book may be illustrated by the following quotation from page 3:

> Inquiring minds have a propensity for tracing things to a first cause, and would ask from whence came the great nebula. It could not have sprung into existence already formed. It had an origin which is worthy of a most careful investigation, for it is one of a class that is represented by thousands

of similar bodies in the heavens. May not a conjecture of its antecedents be properly presented here? It is that when the great Creator would form a new system of worlds, having allotted a district of suitable form and dimensions for the purpose, he changes the primordial matter in it from a gaseous condition, in which it had been under the law of repulsion, into cosmical dust, by which slight change it became subject to the law of gravitation.

And the following from pages 72 and 73:

Any matter erupted from the sun can return to it again, as it does constantly from its prominences. But there seems to be a repulsion between all comets and the sun. They are attracted toward it, but never to it. After one revolution the reason may be given that they have established orbits. But that reason does not apply to the first approach. Any other bodies gravitating toward the sun from the depths of space would fall directly upon it. But cometary matter seems to be governed by an unknown law, a law of gravitation limited. There is attraction at a great distance, but repulsion on near approach. Is it not evident from the following quotation? "The great comet of 1843 passed within three or four minutes of the surface of the sun, and therefore directly through the midst of the corona. At the time of nearest approach, its velocity was three hundred and fifty miles a second, and it went with nearly this velocity through at least three hundred thousand miles of corona, coming out without having suffered any visible damage or retardation" (NEWCOMB'S *Popular Astronomy*, p. 251).

Was not that a clear case of mutual shrinkage or gathering of skirts as two persons would gather their delicate robes to avoid contact when passing too near each other?

Occasionally the style falls off to this:

This hypothesis presents, in a greater degree than any explanation heretofore offered, the elements of possibilities in the tissue of forces and their observed effects. Indeed those effects demand a reasonable exposition of producing causes.

The author attempts to solve some of the fundamental problems of geology by giving enormous magnitude to the rendering and triturating effects of the descent of the waters of the supposed primitive vaporous atmosphere upon the assumed hot earth. Respecting this he says:

The inquiry must arise in every thoughtful mind, to what depth will the breaking of the rocky crust extend? What can arrest the destructive action of the water? Will the weight of the débris affect it at the depth of one mile, or two miles, or three miles? No, nothing can resist the explosive power of steam. It opens the way and keeps it open for the

downward progress of water. Nothing can arrest the destruction of the rocky crust so long as there is rock to be broken. The entire solid crust of the earth must be transformed, must be rent into fragments. The water reaches the molten mass below and can go no farther. . . . .

Again the phenomenal changes and the condition of the earth's crust embarrass our powers of description, and even conception. The water having reached the molten mass below the fragmental crust, could go no farther. It had reduced the temperature of the upper surface more nearly to that of boiling water, while that of the molten mass below the broken crust was nearly forty-four hundred degrees higher. The entire mass, thirteen miles in depth of débris and water, is kept in violent motion by the resistless power of steam over the entire surface of the globe.

On this "true basis," in negligence of the most obvious limitations of a well-recognized action, the author builds theories of elevation, vulcanism and stratification, and assumes that he has solved some of the great problems of geology.

Those who are not well versed in what is established will read the book at much risk of mixing needless error with truth, while those who are so versed will probably find it interesting chiefly as a psychological study.

The book is pervaded by an ostentatious piety of the type prevalent in the last century, which is liable to produce a moral effect quite opposite to that intended. True reverence is best displayed by refraining from presuming to know the mind and purpose of the Infinite and by scrupulously dissociating one's imperfect notions from all connection with Omniscience. T. C. C.

Text-Book of Paleontology, by KARL A. VON ZITTEL, translated and edited by CHARLES R. EASTMAN. Vol. I, Part II, pp. 353–706, with 883 wood-cuts. Macmillan & Co., 1899.

After an interval of more than three years since the appearance of Part I, the invertebrate portion of Zittel's Paleontology is at last brought to a conclusion. The plan and scope of this work was discussed at length in a review of Part I, which appeared in this JOURNAL for October 1896; hence it is only necessary to repeat here that the English edition is a composite production, much of Zittel's text being discarded and replaced by original contributions from a dozen different authors, whose names are given on the title-page.

The Grundzüge der Paläontologie, which forms the basis of the present work, is an essentially modern, useful, and very compact treatise. It compasses within 900 odd pages the whole field of paleozoölogy, rather more than one half of the space being devoted to invertebrates. The descriptions of genera are brief but to the point, the illustrations numerous, and the arrangement simple and well-balanced. These are salutary features for any elementary text-book to possess, and the writings of von Zittel have set a high standard for other authors to emulate.

As compared with the original, we note in the first place that the English edition devotes about 200 more pages to the invertebrates, and is enriched by nearly 100 new figures. Over 4600 generic names are enumerated in the index, being about 1200 in excess of the invertebrates treated in the German edition. The amount of enlargement is therefore considerable, and the new genera introduced are mostly those which are of importance in American and British strata.

All the generic diagnoses are of necessity very brief, and large numbers of names are cited without definition, simply as an index to their family position, or degree of family differentiation. Typical or otherwise interesting forms are treated more at length, and in some instances type-species are listed; but the definitions of families and larger groups are as a rule succinctly yet carefully stated. The book serves as an excellent guide for orientation over the different groups and as a catalogue of the more important genera, but does not permit of the identification of less important genera without the aid of special literature. In compensation for this, copious bibliographies are inserted under nearly every caption, those for the Cephalopods and Trilobites being especially complete and all of them brought strictly up to date.

Many radical changes are to be observed in the classification, the responsibility for which, we are told in the preface, lies with the revisers of the different sections. The rearrangement of Pelecypod families and genera by Dr. W. H. Dall is in accordance with the latest conceptions of this eminent conchological authority. Great emphasis is laid by Dr. Dall on the distinctness of family groups, and many well-known genera are taken by him to represent types of new families, or subfamilies. Nor is Dr. Dall alone in this tendency toward elevation of families out of generic characters; it seems to be becoming more and more the fashion in all branches of systematic biology, and probably

the most remarkable illustration of all is to be seen in Professor Hyatt's new classification of Cephalopods. The chapters on Nautiloids and Ammonites, occupying 75 pages, have been entirely rewritten by Professor Hyatt, and represent in epitome a life work expended on the study of these groups. The system followed was proposed in outline at the Boston meeting of the American Association, two years ago. Its essential feature consists in the elevation of the three leading "genera" of von Buch, *Goniatites*, *Ceratites*, and *Ammonites*, together with the Clymenoids of Gümbel, into as many different suborders, and in addition to these, several entirely new ones are recognized among the Goniatites and Ammonites. A large number of genera are made the types of independent families, and the prevailing feature throughout is the comparison of young stages of specialized forms with the adult of primitive types. As the entire life history of Ammonites and other groups are recorded in the progressive changes taking place in the shell, this class of organisms is especially well suited for comparative investigations based on the principle of accellerated development.

The chapter on Trilobites is from the pen of Professor C. E. Beecher, our leading authority on this group. The treatment is much fuller than in the original, and a considerable number of new figures are added. As in the Ammonites it is of prime importance to compare the ontogenetic stages, and this furnishes the key to the new classification of Beecher, since adopted by Cowper, Reed, Bernard, and others, although opposed by Pompeckj. Trilobites are here accorded the rank of a separate subclass, all other crustacean forms being set off against them under the title of Eucrustacea. The latter have been revised for the present work by Professors J. M. Clarke and J. S. Kingsley, with the exception of the Ostracoda, which are accredited to Mr. E. O. Ulrich. A noteworthy point consists in the removal from Crustacea of the Merostomata, including Limulus, the Eurypterids, etc., and associating them with the Arachnids under the head of the *Acerata*, of Kingsley. This step, it is believed, will eventually be acquiesced in by most specialists on these groups. Altogether, the chapters on Arthropods show evidence of most careful revision, and are well-balanced as regards space.

We come lastly to the chapters on Arachnids, Myriopods, and Insects, which have been revised and slighly enlarged by that indefatigable paleoentomologist, Professor S. H. Scudder. Save for being

simpler and briefer, the treatment is much the same as that followed in the *Handbook* of von Zittel, the chapters in question having been prepared for that work by the self-same author. Here also new figures are inserted, a very striking one being Brongniart's restoration of *Meganeura*, a dragon-fly having an expanse of 30 inches between tips of wings. The book concludes with a complete index of genera and subgenera.

The present edition of the von Zittel places in the hands of every English-speaking student a good elementary text-book that has long been needed. It is significant that in the "Eastman translation" so much American material has been introduced, and that so much revision has been done by American specialists.

Regarding the work as a whole we may repeat what was said of the first part, that educators in general owe to Dr. Eastman a deep debt of gratitude for providing our college and higher schools with a "translated, revised, and enlarged edition" of the best manual of paleontology that has ever been written. Professor von Zittel is to be congratulated, not only for the improvement presented by his new elementary text-book, but also, as shown by the results, for having entrusted the preparation of the translated edition to such excellent hands.

CHARLES R. KEYES.

The Gold Measures of Nova Scotia and Deep Mining. By E. R. FARIBAULT. Canadian *Mining Review*, March 1899, Pp. 11, with 6 plates.

E. R. Faribault, of the Canadian Geological survey, has lately announced the results of fifteen year's work on the gold measures of Nova Scotia. These results are of great interest, both from a scientific and economic standpoint.

The gold measures of Nova Scotia are confined to the metamorphic Lower Cambrian quartzites and slates, forming a belt along the Atlantic coast from 10 to 75 miles wide. Intruding these rocks are large masses of granite occupying nearly a third of the superfices of the province. These were intruded in Silurian time, after the folding of the strata and deposition of the gold-bearing quartz, and need not be considered. The originally horizontal quartzites and slates have been folded into a series of huge undulations roughly parallel with the seacoast. The amplitude of the folds varies considerably, but

the average is about three miles. A section of 35 miles across the gold measures gives eleven anticlines. These folds have been greatly flexed in a direction transverse to the closer folding, so that they form long domes. In the folding, the upper strata have slipped upward on the lower strata, these movements taking place largely along the soft slate layers between the hard quartzite layers. This has resulted in compression along the sides of the folds and the formation of openings along the crests.

Gold-bearing quartz has been deposited in the openings near the crests of the domes formed by the slipping of the layers. The veins thus deposited thin out rapidly along the limbs of the folds, but keep their size along the pitch for some distance, though finally pinching out. Where the folding has been close and the legs of the anticline form an angle of less than 45°, the large bodies of quartz on the anticline are called *saddle reefs*, the name given to such formations in Australia.

As yet no general operations have been carried on to any depth through the arch core of the folds in Nova Scotia, although at various places a number of veins have been found. However, from analogy with the Australian gold-bearing veins occurring in a similar manner, it is believed that the quartz veins in Nova Scotia will be found to recur many times in depth.

The laws governing the position and extent of the zones of quartz veins, as well as the laws governing the position and extent of the "pay streaks" within the veins, are given in detail.

This work of Mr. Faribault's will be of immediate practical advantage to mining men, some of whom have already testified to its accuracy and value. It is another instance, lately of frequent occurrence, of geological work done from a purely scientific standpoint having direct economic value.

From a scientific standpoint also, the results are of interest as illustrating a principle of ore deposition. In many districts, and particularly in the Lake Superior District, it has long been known that ore deposits were partial concentrates in pitching troughs by decending waters. Van Hise has lately enunciated the principle that the openings in arches or pitching folds are favorable places for the concentration of ore deposits by *upward moving waters*. The formation of the gold-bearing veins of Nova Scotia seems likely to have occurred in this way.

C. K. L.

Maryland Geological Survey, Vol. III, Baltimore. The Johns Hopkins Press, 1899.

This volume consists of the application of geology to the "permanent and economical improvement" of the roads of Maryland. It consists of 461 pages and 80 pages on "Laws of Maryland relating to highways." There are 35 plates, including 14 maps, and 38 figures.

The state geologist, Professor William Bullock Clark, contributes the Preface, Part I, Introduction, and Part II, "The Relations of Maryland Topography, Climate and Geology to Highway Construction." The author discusses the "dependence of the highways upon the surface configuration of the land," and their dependence upon the underlying formations; the effects produced upon the roads by temperature changes, precipitation and winds. He gives the areal distribution of the various geological formations of the state, accompanied by a map, and with a hint to roadmasters to make use of the information. Then follows a discussion of the road materials of the state and their relative values for road building.

Part III, "Highway Legislation in Maryland, and its Influence on the Economic Development of the State," is contributed by St. George Leakin Sioussat.

Part IV, "The Present Condition of Maryland Highways," and Part V, "Construction and Repair of Roads," are by Arthur Newhall Johnson.

The condition revealed in Part IV amply justifies the Survey in its undertaking to direct attention to the need and the methods of improvement. Yet Maryland has some excellent highways, and the average condition of its roads is perhaps as good as in most of the states. On the other hand Massachusetts and Connecticut are states which are noted for their good roads. In Part V Mr. Johnson gives practical instruction on grading, drainage, and surfacing which will be of great service in road-building,

The following Parts, VI, VII, VIII, are by Harry Fielding Reid. Part VI treats of the "Qualities of Good Road-Metals and the Method of Testing them." In this chapter Professor Reid deals with the following series of laboratory tests of materials, viz., microscopic test; abrasion test; crushing test; cementation test. The results of these tests upon various rocks are illustrated. Part VIII, relative to "The Advantages of Good Roads," is adapted to awaken an interest in road improvement.

If the people of Maryland shall become convinced that, in addition to incidental advantages, "a sum in the neighborhood of three million dollars would be annually saved by improving the important roads of the state," there will be no difficulty in getting appropriations for road building and repairs. The volume will exert a wide influence for the betterment of the roads of the country. As a piece of bookmaking it is exceptionally good. The type is clear, the illustrations are apt and well-made. The Survey is to be congratulated upon presenting in such excellent form a volume replete with valuable information and suggestion.

JAMES H. SMITH.

Maryland Weather Service, Vol. I, Baltimore. The Johns Hopkins Press, 1899.

The Maryland Weather Service is conducted under the auspices of the Johns Hopkins University, the Maryland Agricultural College and the U. S. Weather Bureau.

In Part I, Introduction, Professor William Bullock Clark gives a brief history of the State Weather Service and presents "lines of investigation pursued by the Service." These are topography, physiography, meteorology, hydrography, medical climatology, agricultural soils, forestry, crop conditions, flora, and fauna. He also enumerates the previous publications of the Service.

Part II consists of "A General Report on the Physiography of Maryland, by Cleveland Abbe, Jr. Professor Abbe discusses physiographic processes in general and takes up briefly each of the physiographic provinces of the state. A study of stream development of the Piedmont Plateau leads to the conclusion that [1] "The streams of the eastern division of the Piedmont Plateau have been superimposed from the formerly more extensive Coastal Plain cover."

Thus the explanation of McGee is confirmed by detailed field work—at least in the eastern part of the plateau. On page 132, Professor Abbe uses the phrase "Topographic Valences of the Rocks." The word "valence" in this connection is not defined, but immediately following the heading quoted the author speaks of the "different degrees of resistance which they [rocks] offer to weathering and erosion." These resistances appear to be what is meant by the term "valences." Since valence is used in a quite different, but definite,

[1] P. 216.

sense in chemistry; and since it has still another meaning in biology, we doubt the wisdom of giving the word a third technical meaning in geology. And if it means resistance to denudation the coining of a new term does not seem to be demanded.

Part III consists of a "Report on the Meteorology of Maryland," by Cleveland Abbe, F. J. Walz, and O. L. Fassig. Professor Abbe takes up Dynamic Meteorology and its Applications; Climatology and its Aims and Methods, and Apparatus and Methods. Among many suggestive topics we note with approval the emphasis put upon "Paleoclimatology" — a subject that is receiving increasing attention on the part of geologists. Professor Abbe strongly states the case when he says,[1] "Geology is primarily a study of the influence of the overlying atmosphere upon the earth beneath. It is, therefore, an essential part of the study to understand the climates and the changes in climate that have prevailed since the earth began its annual course around the sun and its diurnal revolution around its axis. The study of modern climates must be considered by the geologists as simply an introduction to the equally important study of ancient climates and the work done by them." Dr. Fassig presents "A Sketch of the Progress of Meteorology in Maryland and Delaware." Mr. Walz gives an "Outline of the Present Knowledge of Meteorology and Climatology of Maryland." The weather maps, showing types of weather in various places and seasons are well selected and are very instructive. There is a chart showing normal temperature and pressure for Maryland, including Delaware and the District of Columbia for each month of the year; also one each for spring, summer, autumn, winter and for the year. There are also many tables for reference.

The volume is a handsome one of 566 pages, 54 plates, some of which are colored, and 61 figures. All of the illustrations except Plate XXXV are pertinent to the subject discussed and add much to the value of the volume. Plate XXXV is a picture of the office of the Weather Bureau at Baltimore. It adds nothing of scientific value and would therefore better have been omitted. It seems ungenerous to mention so small a matter, for the volume is presented in an almost faultless form both as to subject-matter and as to mechanical execution.

JAMES H. SMITH.

[1] P. 304.

Principles and Conditions of the Movement of Ground Water. By FRANKLIN HIRAM KING, with a theoretical Investigation of the Motion of Ground Waters, by CHARLES SUMNER SLICHTER. Ext. Nineteenth Ann. Rep. U. S. Geol. Survey, Part II, 1899, pp. lxi + 384.

This important paper bears throughout evidences of the painstaking industry that marks all of Professor King's work. It deals first with general considerations relative to the amount of water stored in the ground in different kinds of rock. For the Dakota sandstone he assigns 15 to 38 feet of water for every 100 feet in thickness of the rock. The water in the Potsdam sandstone of Wisconsin and adjoining states he makes equivalent to an inland submerged sea having a mean depth of 50 to 190 feet of water for the area occupied. In regard to the superficial soils and sands, Professor King gives more detailed data, as this lies in his special field of investigation. A saturated sand carries from 20 to 22 per cent. of its dry weight of water, while the soils and clays range from these values all the way up to 40 and even 50 per cent. of their dry weights. "Since a cubic foot of dry sand weighs from 102 to 110 pounds, while soils, clays and gravels range between this and 79 pounds, we have a ready means of expressing quantitatively the water which is continually stored in this mantle of loose material when it lies below the plane of saturation." In a table of actual determinations where loamy clays and very fine sandy soils are involved, 2 feet of water in 5 feet of soil below the horizon of saturation are shown. When soil does not lie below the plane of saturation it usually contains 75 per cent. of the amount required for full saturation, except during dry times when a surface layer of one to five feet thick falls below this. Even where the plane of saturation lies below a large thickness of soil there is still a large storage capacity for water.

In rocks other than sandstones and soils the percentage is usually very much smaller. Its cumulative magnitude is indicated by the statement that so small an amount of water as 0.0023 of the weight for 5000 feet of the earth's crust is large enough to form a continuous sheet about the globe 30 feet deep. It is believed that water penetrates the crust to depths even exceeding 10,000 feet. Reckoned at 1 per cent., with a specific gravity of rock of 2.65, the amount contained would be a layer 265 feet thick. Of course the amount in the upper horizons is

relatively large and that in the lower very small. An estimate of this kind gives an impression large or small according to the point of view. Regarded by itself, it is large, but compared with the whole hydrosphere it is but a small factor and does not very appreciably add to the oceanic volume. It probably does not amount to so much as the probable error in the estimation of the volume of the ocean and other superficial waters. If the water of hydration be added to it, the statement may not improbably still hold true.

In the treatment of the general movements of the ground water three categories are recognized: (1) Gravitative, (2) thermal, and (3) capillary movements. The oscillations in the flow of springs and artesian wells are illustrated by autographic records and their relations to barometric changes demonstrated. Even the sudden barometric changes accompanying a shower are sometimes sharply recorded. Diurnal changes in temperature are shown to effect the rate of seepage. This is attributed chiefly to the indirect effect of the temperature through the expansion of the gases in the soil. Movements of ground water are ascribed to rock consolidation and crust deformation. Of the 25 to 50 per cent., by volume, of water inclosed in the sediments, when first laid down, a considerable part is forced out as the sediments settle into greater compactness, and finally pass into indurated rock. By an ingenious device on automatic flow from the base to the top of a cylinder of settling sediments was secured against a head of six inches. In the dynamic consolidation of rocks, a still larger per cent. of the inclosed water is forced out. The growth of grains and the filling of pore-spaces is a concurrent source of expulsion of water. Limestones as now taken from the quarries have, as a rule, a pore-space varying from less than 1 per cent. to 7 or 8 per cent. at most; so that the final formation of every 1000 feet of compact limestone means an expulsion of water from these beds during the process of growth and consolidation amounting to not less than one fourth, and possibly as much as one half, of the present volume of the rock.

For the capillary movements of ground water recourse must be had to the paper itself, as the tables cannot be briefly and adequately summarized.

The configuration of the ground water surface is illustrated by contour maps and the flow dependent on this configuration diagrammatically indicated. The changes in the configuration that result from precipitation are shown by tables and by diagrams.

Then follows an account of an elaborate series of investigations of the flow of water through soils, sands, rocks, and other porous media. These are much too extended to be reviewed in detail. They furnish data of prime importance to studies in irrigation, water supply, and various other inquiries that involve the size of grain, the pore-space, and the various elements of resistance to percolation. The industrial as well as the scientific value of these determinations, with which are collated those of others, is obvious.

The value of the experimental study of Professor King is greatly enhanced by the theoretical investigation of the motions of ground water by Professor Slichter. The treatment is mathematical and can be read only by those who are familiar with its elegant language. The excellent illustrations, however, translate some of the more vital parts into the vernacular. Those which relate to the interferences of flows into artesian and other wells are especially instructive.

T. C. C.

Les Lacs Francais. Par ANDRÉ DELEBECQUE. Ouvrage couronné par l'Academie des Sciences. 436 pp., 22 plates, and 153 figures in the text. Accompanied by an atlas of 10 maps. Paris: 1898.

This elaborate work is divided into ten chapters, and a brief outline is here given of the substance of each:

I. *Distribution.*—Most of the lakes of France are in the mountains, the Alps, the Juras, the Vosges, and the Pyrennees; but there are some in the central plateau, some along the coasts, and still others which do not admit of ready classification. The total number of lakes given is between 460 and 470, but many of them are so small that in our own country they would be called ponds.

II. *Depth.*—The second chapter has to do with the depth of the lakes, and the chartings of the soundings.

III. *Description.*—The third chapter is a description of the principal lakes, the description taking account of the depth, the area, the position, etc. Contour maps of the basins of more than forty lakes are given on the plates. Of lakes more than 25 meters deep, there are thirteen in the Alps, eleven in the Juras, two in the Vosges, eight in the central plateau, twelve in the Pyrennees, and one on the coast of the Mediterranean, forty-seven in all. Of lakes more than 1000

hectares (approximately four square miles) in area, there are in the Alps two, in the Juras one, along the Atlantic coast four, and along the Mediterranean coast two. Even of lakes more than 250 hectares in area (approximately one square mile) there are but thirteen. It will be seen therefore that most of the lakes are very small. The tables show that the depth of many of them is great in comparison with their area.

IV. *Topography.*—The fourth chapter deals with the character of the topography and relief of the lake bottoms. Few of the lakes have great depth. Lake Geneva has a maximum depth of $\frac{1}{21\frac{1}{7}}$ of its length and $\frac{1}{5\frac{1}{4}}$ of its width, but these ratios are exceeded by many of the smaller lakes. The deepest lakes in proportion to their area are in the Pyrennees. Here Lac Bleu has a depth of 120 meters with an area of but 47 hectares. In the lake bottoms are recognized (*a*) the marginal plains, partly wave cut and partly wave built; (*b*) the tallus slopes (a talus slope of 87° runs down to a depth of 42 meters in one case, and a slope of 63° to a depth of 100 meters in another), and (*c*) the bottom flats. In the large lakes the sensible flat (or flats) at the bottom is some considerable fraction of the total area. In Lake Geneva the bottom flat of an area one twelfth of the total area of the lake has a relief of less than five meters. These flat bottoms are naturally more distinct in the large lakes than in the small ones. Certain more or less accidental features are recognized in the topography of the lake bottoms. Here are classed deltas, submerged valleys, ravines, hills and islands and funnels. The latter are rare, and represent either places where springs enter the lake, or where sub-surface drainage escapes. Two or three remarkable instances are cited, especially in Lac d'Annecy.

V. *Nature of the bottoms.*—The nature of the bottom is the topic of the fifth chapter. The bottom consists in part of alluvium, and in part of the rock in which the basin occurs. The alluvial material is found to vary both microscopically and chemically with the nature of the rock of the basin. Numerous tables of results are given. The following conclusions are reached: (*a*) The material at the bottom of the lake varies with the rock. In limestone basins calcareous matter dominates, while in basins in siliceous rocks, quartz is most abundant. (*b*) The mean composition of the sediment in the lake is not the same as the mean composition of the rocks in the basin. For example, the sulphates are essentially absent in certain lakes whose

affluents flow over gypsum, or whose shores are partly of gypsum. On the other hand, sulphuric acid is found in small quantity in lakes where there is no gypsum adjacent. Again, calcium is abundant in basalt, but not in the sediment in lakes in basaltic regions. Alkalis are plentiful in granitic rock, but only sparingly present in the lakes in granitic basins. The alkalis and alkaline earths are carried off in solution, chiefly as carbonates, while the silica stays behind and is thus concentrated. (*c*) The composition of the sediment varies in different parts of the same lake.

Sediment is absent in the bottom of the lakes where the slope is too steep for it to rest, in general where the slope is over 45°, and where local conditions have prevented deposition, as where springs enter or where drainage flows out. Sediment is also absent where currents have been effective at the bottom.

VI. *Supply and loss.*—A chapter is devoted to the supply and loss of water, and to the variations in the levels of the lakes. An interesting section is given to the average length of time which water stays in lakes. This is determined from the volume of the lake, and the rate of outflow. Thus in Lake Geneva, it is found that the average stay of water in the lake is eleven years and seventy-three days; in lake d'Annecy three years and one hundred and thirteen days; in Lake Chaillexon five days. Many other calculations are given, all of which tend to show that the duration of the stay of water in lakes is extremely variable. Lakes with surface outlets are found to change their levels but slightly. Data on this point seem somewhat imperfect, but the maximum known fluctuation in the case of lakes having surface outlets is three meters. In lakes having sub-surface outlets, fluctuations of level are far greater. They appear also to be greater for small lakes than for large ones. Thus the level of Lake Chaillexon between August 19, 1892 and December 31, 1895, fluctuated sixteen meters.

VII. *Temperature.*—The tables of temperature given show that the water at the bottoms of the deep lakes varies very little, and that it is near the temperature of greatest density all the time. The tables show that in most lakes there is a well-defined zone which separates the warm (during most of the year) water above from the cold water below, the transition being usually rather abrupt. This zone of transition is rarely more than twenty meters below the surface, and sometimes not more than ten. The causes determining temperature are considered. Aside from (*a*) climate, the effect of which is obvious, (*b*) the average depth, (*c*)

the form and orientation of the lakes, and (*d*) the sources of supply, influence their temperature. The form and orientation of the lakes is of importance in connection with the winds. Lakes which are oriented so as to allow winds to exert their most important influence in the generation of currents, have their temperature equalized in the vertical sense, through the return currents. Circulation is thus shown to be of more importance than conduction in equalizing the temperature between top and bottom. The rôle of affluents in determining lake temperatures is very variable. It depends on the size of the lake, the average stay of the water in the lake, and the nature of the affluents themselves. Following Forel, the author emphasizes the paradoxical fact that the waters of the glacial Rhone raise the temperature of Lake Geneva, the temperature of the river being notably above that of the lower part of the lake at all times, while the large amount of sediment in the river water so increases its specific gravity as to cause it to descend much below the zone of lacustrine temperature corresponding to its own. Sub-surface affluents exert an important influence in their immediate surroundings, or, if the lake be very small, on the whole volume of water. The temperatures of these affluents being essentially constant, the temperature of the lake is differently affected by them in different seasons. Lakes are classified by the author, following Forel, on the thermal basis, as *tropical*, *temperate*, and *polar*. The tropical lakes are those whose surface waters do not reach 4° C.; the temperate lakes are those the surface waters of which are sometimes below and sometimes above 4°; while the polar lakes are those whose surface waters never rise above 4°. Of the first class the larger part of Lake Geneva, and certain salt lakes near the shore are the only representatives. To the second class most of the lakes of France belong, but there are a few representatives of the third class in the Pyrenees, and in certain other high altitudes.

Chapter VIII deals with the *transparency*, *color*, etc., of the lakes. The lakes are partly blue (few), partly green (the larger number), and partly yellow (a large number.) The color is found to be influenced by (*a*) the dissolved organic substances, such as humic and ulmic acids; (*b*) the presence of vegetable and animal organisms in the water; and (*c*) the inorganic sediment. The transparency is found to vary within a given lake with the season, and with the position of the station. It is greater in winter than in summer, and increases with increasing distance from the debouchures of streams. The water of the blue lakes is

most transparent, that of the green less, and that of the yellow least.

IX. *Matter dissolved in the water of the lakes.*—With the exception of the salt lakes, none of the lacustrine waters contain so much as one gram of solid matter per liter, and in five cases only does it exceed .3 gram per liter. There are notable variations in the amount and kind of dissolved matter depending upon the character of the basin, and there are notable variations in the same lake in different seasons, and in different parts during the same season. In the summer the warm waters in the upper portions of the lakes are poorer than the colder waters below, in some of the dissolved substances, especially Ca CO_3 and SiO_2, while in winter the solutions are nearly uniform throughout. In general, the lake waters have less solid matter in solution than the inflowing rivers, showing that dissolved matter is lost in the lakes. This loss is attributed largely to precipitation, and it seems to be implied that calcareous tufa is of very common occurrence. This would hardly hold for the greater number of the lakes in the United States. With reference to dissolved gases, the conclusion is reached that the amount of these gases, chiefly CO_2, O, and N, are independent of pressure, but that they increase with depth on account of the lower temperature. The amount of carbonic acid gas dissolved far exceeds that of oxygen and nitrogen together, whether measured by weight or by volume. Little account is taken of other gases.

X. *Geological position and origin.*—The classification of lakes in general is briefly outlined, and the lakes of France fitted to the classification. Two primary classes of lake basins are recognized: (1) Those produced by barriers of one sort and another, and (2) rock basins. Of the barrier basins there are many types, most of which are represented in France. The barriers are of various types as follows: (1) *Landslides.* Lake basins produced in this way are found in the Alps, the Juras and the Pyrenees, but are not numerous. (2) *Ice.* No existing lake in France owes its existence to an ice barrier. One extinct lake is so classed. (3) *Moraines.* The moraine of an existing glacier is the barrier which gives origin to a single lake,—Lac Long in the Alps. Lakes which owe their origin to moraines of extinct glaciers are numerous and of several classes. Here belong (*a*) lakes in valleys which were occupied by glaciers, the moraine forming a dam at the lower end of the lake. Of this class there are several representatives in the Alps,

the Juras, and the Vosges Mountains, one in the central plateau, and one in the Pyrenees; (*b*) lakes which result from the blocking of a lateral valley by the moraine of the glacier which occupied the main valley. Of this there are representatives in the Alps, the Juras, and the Pyrenees; (*c*) lakes which lie in basins occasioned by the irregular deposition of drift. But two lakes fall into this category, one in the Alps, about which there is some question, and one in the Juras. In our own country lakes of this class are more numerous than any other. (4) *Lava.* Several lakes, the basins of which are formed by lava dams, are found in the central plateau. (5) *Volcanoes.* Two lakes in the central plateau owe their origin to growth of volcanoes in the bottoms of valleys. (6) *Craters.* Several lakes in the central plateau occupy craters. (It is not altogether clear why crater lakes should be classified among the lakes produced by barriers). (7) *River alluvium.* Lakes formed along rivers by the deposition of alluvium are represented by a few lakes in the Alps, Juras and along the Mediterranean coast. (8) *Bars.* A few lakes on the coast owe their origin to the construction of bars which shut off a portion of the sea water, leaving inland basins. (9) *Dunes.* There are several lake basins completed by dune barriers along the Atlantic coast.

Of the lakes which occupy basins in the rock, one group owes its origin to internal forces. In this category belong the basins produced (1) by violent volcanic disturbances, such as explosions, of which there are several examples in the central plateau; and (2) lakes produced by secular movements. To this class belong several lakes in the Alps (Geneva and d'Annecy), and in the Juras, though concerning the origin of the latter there seems to be some question. Of the lake basins originating through the action of external forces, there are (*a*) those resulting from solution effected by underground waters, represented in the Alps and along the Atlantic coast, in the Juras, along the Mediterranean, and in one or two other places; (*b*) lakes due to erosion of rock along fissures, as where a fissure crosses a watercourse; and (*c*) basins due to excessive local erosion by the ice, represented in the Alps by several examples, in the Juras by one possible example, in the Vosges by one, in the central plateau by several, and in the Pyrenees by a considerable number. Here belongs Lac Bleu, of extraordinary depth. It is probable that in the production of many of the lake basins more than one factor has been involved.

XI. *The life history of lakes.*—After a consideration of the various causes which may bring the life of a lake to an end, the history of a few of the principal lakes of France is sketched. The level of Lake Geneva has been lowered about 30 meters since the glacial time. It had one stationary level between the highest and the present levels, when the water stood 10 meters higher than now. The other lakes especially considered are Bourget, which has also been lowered in post-glacial time, and d'Annecy, which was formerly 15 meters lower than now. The rise was occasioned by alluvial deposits in the valley of the Fier, to which the outlet of the lake flows. These deposits have dammed the exit. The history of Lacs de Saint Point and Remoray —in the Juras— is also outlined, the interesting point being that they were formerly one lake, now divided into two by the growth of a delta completely across the narrow basin. The growth of deltas seems to have played a large part in the history of many of the mountain lakes. This is the natural course of events where torrential streams debouche into the standing water. Many other lakes appear to have had their areas greatly diminished by similar processes. Reference is also made to certain extinct lakes, and the criteria by which their former existence is recognized are briefly given.

The figures in the text of the volume are largely half tones, which unfortunately, cannot be said to be of more than medium grade. It could have been wished also that the few maps of the text which show features other than the topography of the lake bottoms, could have been clearer. On the whole they have so much ink, that it is difficult to find the points sought. It is always a serious problem to make a map clear, and at the same time get a great deal on it, and in this case the difficulty has not been overcome.

R. D. S.

On the Building and Ornamental Stones of Wisconsin. By. E. R. BUCKLEY, Ph.D., Madison, Wis., 1898. Pp. xxvi + 544. Bull. No. 4. Economic Series No. 2 of the Wisconsin Geological and Natural History Survey.

Dr. Buckley's report is one of the most compendious volumes on the subject of building stones published in recent years. Of the three parts into which the subject-matter is divided the first treats of the demands, uses, and properties of building and ornamental stones in general. This is a valuable though brief discussion of the subject.

Part II, which forms the bulk of the volume, begins with a chapter on the geological history of the state, followed by a detailed description of the different quarry-areas. The igneous and metamorphic rocks are first enumerated and described, and the author clearly shows the variety as well as the architectural beauty and value of the granitic rocks of the state. The only metamorphic rock mentioned is quartzite.

The sandstones are divided into three classes, partly on a geographical and partly on a geological basis. The first class includes the northern Potsdam sandstone, comprising what is ordinarily known as the Lake Superior brownstone, which apparently differs quite markedly from the sandstones of the southern Potsdam area and the St. Peter's formation included in the second and third classes. Neat sketch maps show the location of the quarries with reference to the markets and the transportation facilities. The limestone quarries are conveniently divided on a geological basis into (1) the Lower Magnesian, (2) the Trenton, and (3) the Niagara.

Chap. VII relates to the areas from which suitable stone for different uses may be obtained, such as building stone, bridge stone, paving blocks, etc. It has a direct economic bearing that will no doubt be appreciated by architects, builders and dealers in stone.

In the next chapter there is a discussion of the results of physical tests which are conveniently summarized at the end of the chapter in a series of thirteen tables. The crushing strength may really have little significance to the scientist, but has great weight with the architect. In this respect the Wisconsin granites and limestones have shown surprising results. The excess of strength of the Wisconsin granite over that from other states is possibly not so great, however, as the tests might lead one to believe. Granting that Gilmore's formula is incorrect, it is not conclusive proof that a large cube is not stronger than a small one in a ratio greater than the comparative areas of the faces. It might have been better to have given the dimensions of the cubes of the granites tested from other states along with the figures quoted and permit the reader to draw his own conclusions.

One of the most important sections of the report has to do with the effects of freezing and thawing on the strength of building stones. Numerous experiments have been made leading to the conclusion that freezing and thawing, continued for a considerable period, lessen the strength of rock, and that the loss in strength is in a general way proportional to the crushing strength of the rock. In other words, the

loss of crushing strength is greater in rocks in which the porosity is low and the size of the pores small, than in rocks in which the pore space is high and the pores large. This conclusion is diametrically opposed to that which is popularly current. The explanation of this unexpected result is that in the case of rocks where the pores are large the included water is given off with sufficient rapidity to avoid the evils of freezing, while in the case of close-textured rocks which are saturated when frozen, the water does not escape, and the injury to the rock is greater. This is a point of great practical value, as well as of theoretical interest. The results of the experiments are given in detail in tabulated form. Part II also contains a set of tables in which are given the results of the various other physical tests to which the building stones of Wisconsin have been subjected.

Part III is an appendix in which composition, kinds of stone, and rock structures are discussed.

The form of the report is a convenient one, the binding is neat and attractive, the illustrations are numerous and for the most part well chosen. A carefully prepared map of the state is folded in the text. An attractive feature is the representation of the stones in their natural colors. No verbal description could arrest the attention so effectually or give the reader so vivid an idea of the beauty of the stone, as these artistic plates. If the printer is not at fault, however, one might wonder why the beautifully colored granite on Plate XII should be called gray.

The person who can write a perfect report on building stones has not yet attempted it. In Dr. Buckley's report there are some points which some of his readers might wish to change. Some are matters of personal taste and all are of somewhat minor importance compared with the much valuable matter forming the body of the report. Petrographers may not all agree entirely with the distinction between gabbro and diabase (p. 447). Some of the readers may not agree with the relative importance placed upon the different cements in sandstone given on p. 450, or with the conclusions about the use of quartzite on p. 455. All those who might agree with the author that "the joints in igneous rocks are more numerous than in the sedimentary" might not agree with him that it is "owing to the greater length of time through which they have been subject to dynamic action" (p. 459).

The report represents a vast amount of careful and conscientious work on the part of Dr. Buckley and will no doubt prove a valuable

handbook in the stone trade of Wisconsin. While it is prepared primarily in the interests of the stone industry of Wisconsin, it has much of general interest to persons outside of the state, and both Dr. Buckley and the director of the Wisconsin Geological and Natural History Survey are to be congratulated on presenting to the public such an interesting, attractive and valuable contribution on the subject of building stones.

T. C. H.

Irrigation and Drainage. Principles and Practice of their Cultural Phases. By. F. H. KING. The Rural Science Series. The Macmillan Company, pp. 502, 8vo. 1899. Amply illustrated.

In this work there is brought together a vast amount of experimental and experiental data relative to the physics of soils and their relations to water and air. These data are given in both their analytical form in the shape of tables, diagrams, and other modes of scientific expression, and in their concrete industrial form as exemplified in growing crops and in drainage and irrigation appliances. The treatment is very clear and specific and at the same time very compact. It is a conspicuous example of *multum in parvo*, if 500 close-set pages do not make the expression inapplicable. The author has personally studied the irrigation systems of Europe as well as those of this country, and has himself conducted careful experiments bearing on the fundamental principles involved. While thoroughly practical in its bearing, the treatment is firmly controlled by the scientific spirit. It is an admirable blending of good science and good technology.

T. C. C.

The Coos Bay Coal Field, Oregon. By JOSEPH SILAS DILLER. Extract from the Nineteenth Annual Report of the U. S. Geol. Survey, 1897–8, Part III, Economic Geology.

This paper deals almost wholly with economic interests of a very local character; and yet it is not without some facts of general interest. It is a description of a coal field of very limited extent situated on the coast of Oregon 200 miles south of the Columbia River. The coal is of Eocene age. Fossils of fresh and brackish water type are found in

immediate connection with the coal, while marine shells are found in the sediments separating the beds.

The seams contain true coal and "pitch coal." The true coal is of good quality, containing little ash. Much of it is "fat," containing as high as 66 per cent. of volatile matter. The "pitch coal" is found in veins and irregular masses in or near the true coal. The latter part of the paper is devoted to a discussion of the "pitch coal" by William C. Day, who concludes that it is an *asphalt*, as it shows none of the characteristics of coal.

W. T. LEE.

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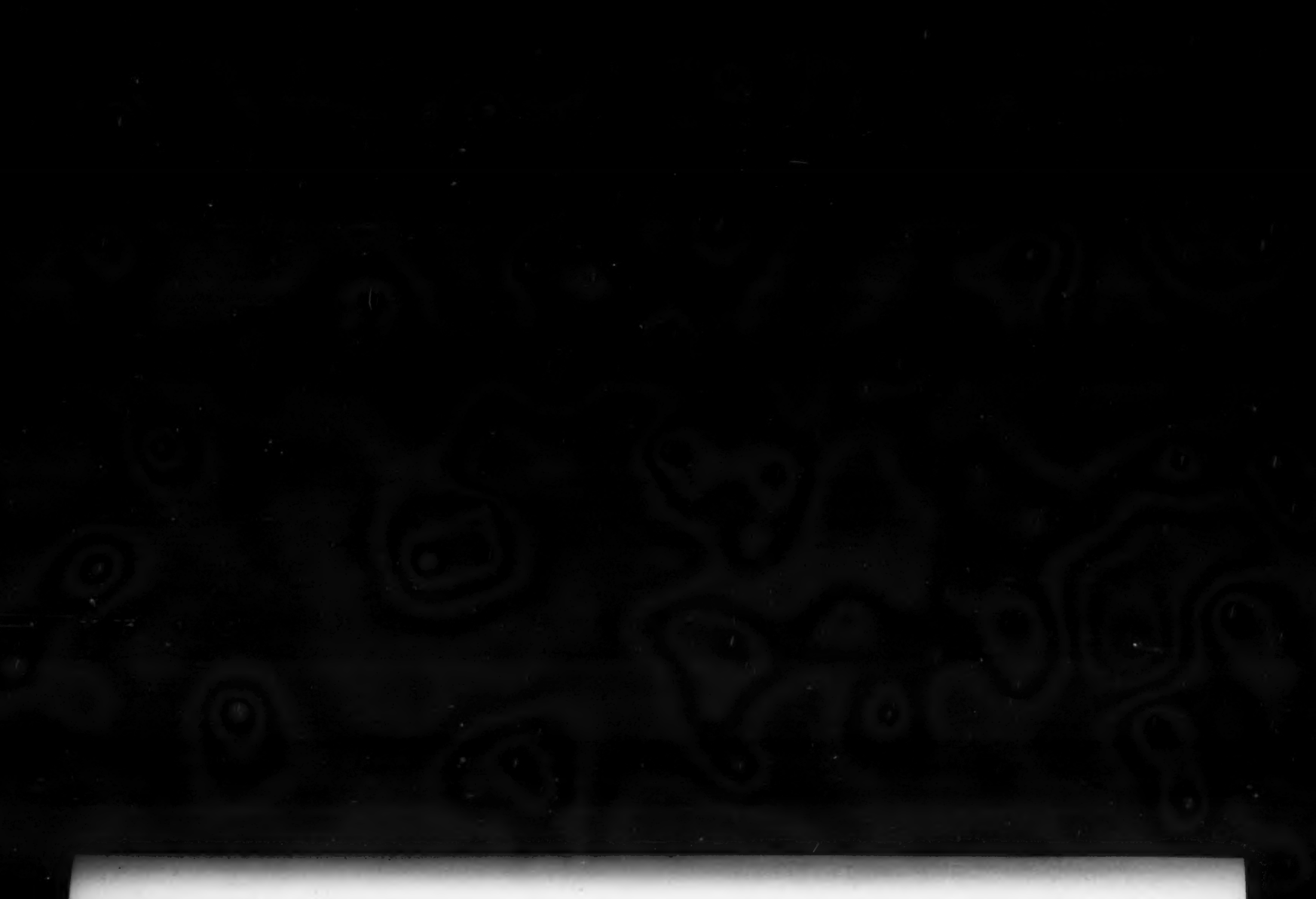
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